

Ecological Benefits Assessment Strategic Plan

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SAB REVIEW DRAFT**

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United States Environmental Protection Agency
Washington, DC 20460

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Foreword

The U.S. Environmental Protection Agency (EPA) recognizes the need to improve its ability to assess ecological benefits arising from EPA policies and actions given the increasingly complex tradeoffs inherent in environmental protection. To identify the efforts needed to improve its ecological benefits assessments, EPA has developed this *Ecological Benefits Assessment Strategic Plan*, hereafter referred to as the EBASP or “the Plan”. The goal of the EBASP is to improve EPA's ability to identify, quantify, and value the ecological benefits of its activities.

The Plan was initiated in June 2002 during work planning discussions among a group of EPA managers on current and future efforts regarding ecological benefits assessment at the Agency. Between November 2002 and April 2003, a series of informational meetings were held to determine the extent to which ecological benefits are quantified and valued to support environmental decision-making at EPA and elsewhere. Both ecologists and economists within EPA and from other federal agencies were invited to the informational meetings. In December 2002, the Assistant and Associate Administrators of several key EPA offices involved in the project met to discuss the progress to date and to encourage more coordination among the participating offices. As a result of that meeting, a memorandum was sent by the heads of the offices leading the planning process to the heads of all other EPA offices alerting them to the existence of this effort and asking for the cooperation of their staff.

The EBASP has been developed by a workgroup consisting of both management and staff from several EPA offices. Participating offices include the Office of Policy, Economics, and Innovation (OPEI), Office of Research and Development (ORD), Office of Water (OW), Office of Air and Radiation (OAR), Office of Prevention, Pesticides and Toxic Substances (OPPTS), and the Office of Solid Waste and Emergency Response (OSWER). The EBASP has been subject to broad internal Agency review and will be reviewed by EPA's Science Advisory Board (SAB), Committee on Valuing the Protection of Ecological Systems and Services.

The EBASP describes the ecological and economic evaluation approaches currently used at the Agency and proposes a more integrated process for assessing ecological benefits that will require sustained interdisciplinary work by both ecologists and economists. The Plan describes a number of actions that could help the Agency improve its ability to identify, quantify and value the ecological benefits of its activities. Specifically, the EBASP describes various technical and institutional issues and describes actions that the Agency can take to address these issues for six broad topic categories: Cross-Cutting Issues, Planning and Problem Formulation, Evaluating the Effectiveness of Management Options, Analyzing Ecological Changes, Estimating Monetary Values of Ecological Changes, and Supplemental Valuation Approaches. The final section describes a number of immediate activities needed to implement the actions in the Plan.

1 The EBASP does not lay out specific research projects or commit Agency program offices to
2 any particular actions, but provides the programs with a menu of ideas that can be used to develop
3 office-specific Action Plans. The institutional recommendations in the EBASP can help facilitate
4 cooperation across offices, which should further improve Agency benefits assessments. The EBASP
5 focuses on institutional and technical issues that arise most often in national-level ecological benefits
6 assessments and where there are statutory requirements for conducting benefit-cost analyses. Hence,
7 the intended primary audience of the EBASP consists of EPA managers and staff in offices engaged in
8 research in support of benefits analysis in the areas of ecology, related natural sciences, and economics.
9

10 Increased attention to ecological benefits assessment has already begun as a result of the
11 development of the EBASP. A number of activities that will address many of the issues and actions
12 listed in the Plan have already taken place or are in the planning stage. These include workshops,
13 research projects, and grant solicitations. Most importantly, there has been a noticeable increase in
14 collaboration across offices and between ecologists and economists in the Agency. The Agency plans
15 to continue and build upon this momentum.
16

17 The EBASP calls for the organization of interdisciplinary, problem-formulation workshops as a
18 way to identify information needs and to improve benefits assessment processes within specific EPA
19 programs. The first of these problem-formulation workshops was held in February, 2004. Thirty-five
20 ecologists and economists from ORD, OPEI, and OW met to study ways to better estimate the
21 ecological benefits of OW programs; a workshop report containing a list of recommendations is in
22 preparation. The EBASP states that study is needed to determine whether existing ecological
23 monitoring programs, such as EPA's Environmental Monitoring and Assessment Program (EMAP), can
24 provide the data needed to estimate changes in ecosystem services. Research already has been
25 initiated in ORD's National Center for Environmental Assessment (NCEA) to examine EMAP's current
26 and future capacity to quantify changes in services, with a focus on EMAP's Great River Ecosystems
27 monitoring effort. ORD's National Center for Environmental Research (NCER) Science to Achieve
28 Results (STAR) program has funded numerous ecological valuation research grants. A workshop is
29 planned for October 2004 that highlights economic research on ecological valuation currently funded
30 under the STAR program. NCER's STAR 2004 Valuation for Environmental Policy solicitation
31 focused solely on ecological valuation, and many of the priorities identified during the development of
32 the Plan were incorporated into the solicitation. NCER expects that future solicitations also will also
33 draw upon the EBASP and priorities identified in office-specific Action Plans.
34

35 These current and planned activities are just the first steps in improving EPA's ability to assess
36 the ecological benefits of its actions. The actions proposed in the EBASP will provide a basis for
37 continuing improvement. Our hope is that as these and similar activities are conducted, and as more
38 research that addresses the needs outlined in the EBASP is completed, EPA will make great strides
39 toward more fully accounting for the ecological benefits of its environmental policies and management
40 actions.

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In addition to EPA staff who became authors of the EBASP or members of the EBASP steering committee (see previous section), many additional EPA staff members participated in the early informational meetings that helped to inform this Plan. From the Office of Policy, Economics and Innovation (OPEI), meeting participants included Matt Massey, Brett Snyder, Keith Sargent, and Colin Vance of the National Center for Environmental Economics (NCEE) and Gerald Filbin of the National Center for Environmental Innovation (NCEI). From the Office of Air and Radiation (OAR), Allan Basala from the Office of Air Quality Planning and Standards (OAQPS) and Jean Marie Revelt, from the National Vehicle and Fuel Emissions Laboratory, participated. From the Office of Solid Waste and Emergency Response (OSWER), David Cozzie provided input. Glenn Farber, Thomas Steeger, and Les Touart, from the Office of Pesticide Programs (OPP), and Donald Rodier, from the Office of Pollution Prevention and Toxics (OPPT) in the Office of Prevention, Pesticides, and Toxic Substances (OPPTS), also contributed. Participants from EPA’s Office of Research and Development (ORD) included Jeffrey Frithsen, Matt Heberling, Ann Sergeant, and Michael Troyer of the National Center for Environmental Assessment (NCEA); Joan Baker, Richard Bennett, and Anne Fairbrother of the National Health and Environmental Effects Research Laboratory (NHEERL); Rich Baldauf, Craig Barber, Daniel Campbell, Peter Principe, and Rosemarie Russo of the National Exposure Research Laboratory (NERL); Audrey Meyer, Bill Schuster, and Hale Thurston of the National Risk Management Research Laboratory (NRMRL); Tom Barnwell of the National Center for Environmental Research (NCER); and Pam Noyes and Molly Whitworth of the Office of Science Policy. Participants from the Office of Water included Jamal Kadry, John McShane, and John Wilson from the Office of Wetlands, Oceans, and Watersheds (OWOW); Ashely Allen, Charles Delos, Gerry Filbin, David Flemer, George Gibson, Chris Miller, Steve Potts, and William Sweitlik from the Office of Science and Technology (OST); Ginny Kibler from the Office of Wastewater Management (OWM); and Brett Gelso, Mahesh Podar, and John Powers, from the Water Policy Staff (WPS). Several EPA Regional staff also contributed to the information gathering meetings: Rick Durbrow, John Richardson, and Beth Walls from Region 4; Mary White and John Perrecone from Region 5; and Pat Cirone from Region 10.

Numerous staff from other federal agencies also contributed to the informational meetings. Participants from the U.S. Department of Interior (USDOI) included John Charbonneau and Brian Czeck of the U.S. Fish and Wildlife Service (USFWS); Glenn Guntenspergen and William Walker of the U.S. Geologic Service (USGS); and Roy Allen and Robert Winthrop of the Bureau of Land Management (BLM). From the U.S. Department of Commerce, National Oceanic and Atmospheric

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Sabrina Ise-Lovell of OPEI, NCEE served as the EPA Task Order Manager for the EBASP contractor support provided by ICF Consulting under the direction of Beth Binns. George Van Houtven of Research Triangle Institute assisted in developing the EBASP Bibliography, and Peter Bonner of ICF Consulting facilitated the information gathering meetings. Sandra Seymour of ICF provided logistic support. For questions concerning the EBASP, please contact Sabrina Lovell.¹

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List of Acronyms

1		
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3	ABP	Analytic Blueprint
4	ACE	Army Corps of Engineers
5	BCA	benefit-cost analysis
6	BMP	best management practice
7	CAA	Clean Air Act
8	CENR	Committee on Environment and Natural Resources
9	DOI	Department of Interior
10	EBAF	Ecological Benefits Assessment Forum
11	EBASP	Ecological Benefits Assessment Strategic Plan
12	EERS	Environmental Economics Research Strategy
13	EMAP	Environmental Monitoring and Assessment Program
14	EPA	Environmental Protection Agency
15	ETV	Environmental Technology Verification
16	GEAE	generic ecological assessment endpoints
17	HAP	Hazardous Air Pollutant
18	IBI	Index of Biotic Integrity
19	ICR	information collection request
20	LOAEL	lowest-observed-adverse-effect level
21	MA	Millenium Ecosystem Assessment
22	NAS	National Academy of Sciences
23	NCEA	National Center for Environmental Assessment
24	NCEE	National Center for Environmental Economics
25	NCER	National Center for Environmental Research
26	NEP	National Estuary Program
27	NHEERL	National Health and Environmental Effects Research Laboratory
28	NMFS	National Marine Fisheries Service
29	NOAEL	no-observed-adverse-effect level
30	NRC	National Research Council
31	NRMRL	National Risk Management Research Laboratory
32	OAR	Office of Air and Radiation
33	OAQPS	Office of Air Quality Planning and Standards
34	OMB	Office of Management and Budget
35	OMEP	Office of Marine and Estuarine Protection
36	OPA	Office of Policy Analysis
37	OPEI	Office of Policy, Economics, and Innovation
38	OPP	Office of Pesticide Programs
39	OPPE	Office of Policy, Planning, and Evaluation
40	OPPT	Office of Pollution Prevention and Toxics
41	OPPTS	Office of Prevention, Pesticides, and Toxic Substances

1	ORD	Office of Research and Development
2	OSP	Office of Science Policy
3	OSW	Office of Solid Waste
4	OSWER	Office of Solid Waste and Emergency Response
5	OSRTI	Office of Superfund Remediation and Technology Innovation
6	OW	Office of Water
7	OWOW	Office of Wetlands, Oceans, and Watersheds
8	PRISM	Puget Sound Regional Integrated Synthesis Model
9	R-EMAP	Regional Environmental Assessment and Monitoring Program
10	RABA	Risk Assessment for Benefits Analysis
11	RIA	Regulatory Impact Analysis
12	RCT	Research Coordination Team
13	SAB	Science Advisory board
14	SDWA	Safe Drinking Water Act
15	STAR	Science to Achieve Results
16	U.S.	United States
17	USACE	U. S. Army Corps of Engineers
18	USDA	U. S. Department of Agriculture
19	USDOE	U. S. Department of Energy
20	USEPA	U. S. Environmental Protection Agency
21	USFS	U. S. Forest Service
22	USFWS	U. S. Fish and Wildlife Service
23	USGS	U. S. Geologic Survey
24	WTA	willingness to accept
25	WTP	willingness to pay

Executive Summary

Ecological benefits, which are the contributions to human well-being derived from ecosystems, are difficult to evaluate. In principle, economic valuation methods can estimate the net benefits of an environmental policy or action – the benefits minus the costs – which allows comparisons among alternatives. Our limited understanding of ecological and economic systems, however, makes it technically impossible to value all ecological benefits in monetary terms. Therefore, it is imperative that the Agency improve its ability to evaluate the ecological benefits of its policies and actions in nonmonetary as well as monetary terms.

Policies for environmental protection may reduce environmental harm, restore damaged ecosystems, or both. The ecological benefits of such policies depend on their effects on the activities of individuals, households, and firms, which in turn affect the flows of ecosystem goods and services such as drinking water supply, commercial and game fish, food and fiber, timber, natural pollination and pest control, outdoor recreation, energy and nutrient cycling, pollutant filtration, and protection of property from weather extremes.

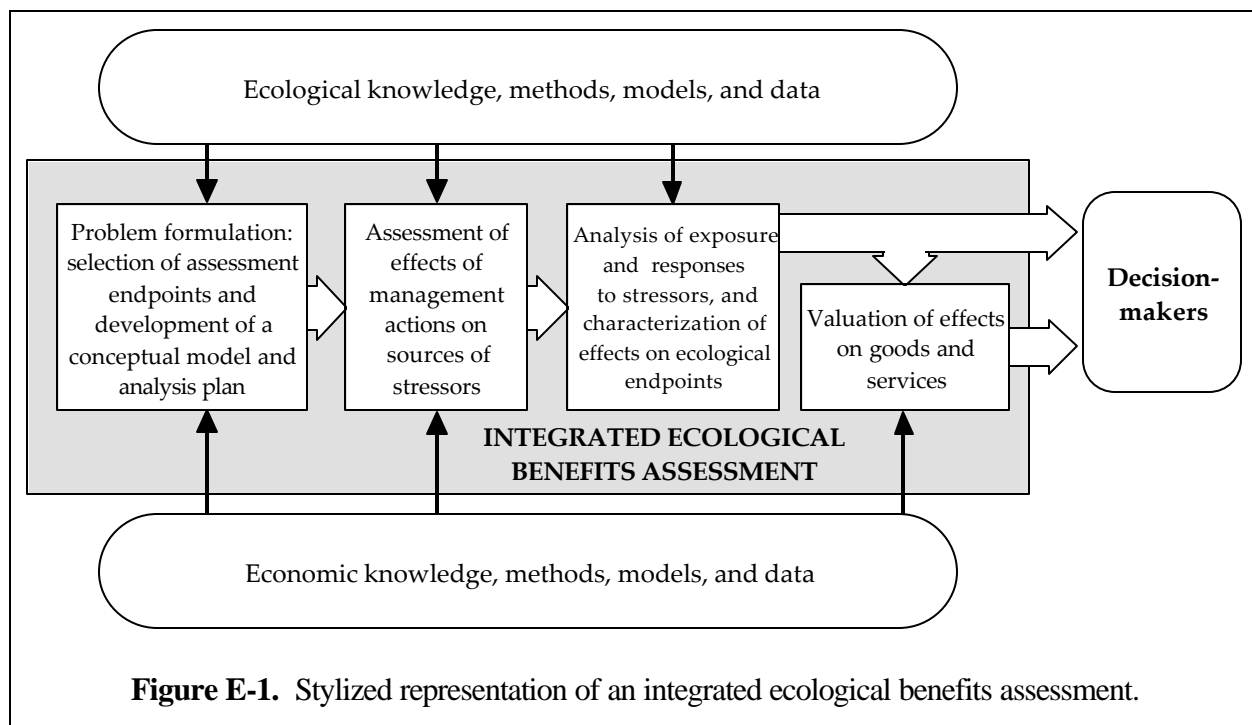
This *Ecological Benefits Assessment Strategic Plan* (EBASP or “the Plan”) has been developed to improve EPA's ability to identify, quantify, and value the ecological benefits of its activities, in order to provide decision-makers with a better basis for choosing among environmental policy options. The EBASP is written for managers and analysts in EPA headquarters offices, and focuses mainly on issues that arise in national-level ecological benefits assessments. The major sections in this Plan are intended to:

- describe the challenge of conducting ecological benefits assessments and characterize previous and ongoing activities;
- describe the current state of the practice of ecological and economic assessments at the Agency, and advocate an integrated interdisciplinary approach to benefits assessment;
- **identify technical and institutional issues that impede EPA's ecological benefits assessments and describe potential directions for future research, data collection, and development of analytical tools;** and
- provide recommendations for implementing the EBASP.

Assessing how EPA policies and actions affect ecological benefits is complex and challenging for several reasons. Knowledge of typically complex ecosystems remains incomplete, and thus some ecological benefits are unrecognized or poorly quantified. Economic values for ecological resources are difficult to estimate, and both ecological and economic data, methods, and models are limited, particularly for use at the national scale. In addition, opinions differ on the desired state of the

environment. In recent years, EPA, other federal agencies, and non-governmental organizations have collaborated in efforts to improve the state of the science and practice of ecological benefits assessment through research, workshops, case studies, meetings, and development of guidance. The EBASP builds on products of these efforts such as economic guidelines, ecological risk assessment guidelines, and recent integrative approaches.

Current practice at EPA shows progress in developing guidance and tools for conducting economic analyses and ecological assessments, but only recently has EPA articulated the need for more interdisciplinary ecological benefits assessments. Figure E-1 portrays a four-stage integrated ecological benefits assessment process, derived from both EPA ecological risk assessment and economic guidelines. Arrows from the rounded boxes illustrate the major points at which ecological and economic understanding inform the assessment. Stages and arrows within the central box indicate that the assessment is a collaborative, interdisciplinary process in which the economic and ecological analysts integrate their understanding, methods, and data in planning and executing the assessment.



The majority of the EBASP is dedicated to describing actions for improving EPA's ecological benefits assessments over both the short and longer term. These are organized under six topics, in similarly-formatted discussions, that identify issues associated with each topic and actions needed to address those issues. Several actions reflect institutional changes needed to improve the ecological benefits assessment process at the Agency. Most actions indicate collaborative activities or directions for future research, data collection, and development of analytical tools that will improve ecological benefits assessments. Topics, issues, and actions are summarized below in Table E-1.

Table E-1. EPA actions to address issues in ecological benefits assessment (organized by topic).

ISSUES	ACTIONS
Cross-cutting issues	
Communication between ecologists and economists within EPA.	Provide formal and informal opportunities for improving communication among disciplines.
	Provide basic training in the fundamentals of other disciplines.
Collaboration between ecologists and economists.	Explore methods for expanding the use of ecological risk assessment information in economic benefits assessments.
	Require multi-disciplinary participation in assessing ecological benefits.
	Develop guidelines for planning and conducting ecological benefits assessments.
Coordination of analytical planning.	Revise EPA's general guidelines for developing Analytic Blueprints.
Primary data needed for ecological benefits assessments.	Increase coordination of long-term, large-scale data collection efforts within the Agency.
	Coordinate with other federal agencies to avoid duplication and to leverage available resources to increase the overall quantity and quality of data collected.
	Use research programs to support studies with relevance to ecological benefits assessments.
	Address perceived bottlenecks in the data collection process.
Inherent variability in ecological and economic systems.	Compile data on inherent variability and develop improved methods to account for it in ecological benefits assessments.
Uncertainty from model mis-specifications in integrated ecological benefits assessments.	Investigate potential common sources of model uncertainty in ecological benefits assessments.
Problem formulation	
Interdisciplinary participation in problem formulation.	Organize a series of program-specific problem-formulation workshops.

ISSUES	ACTIONS
Identifying clear linkages between ecological endpoints, ecosystem goods and services, and benefits categories.	Develop a set of generic ecological benefits assessment endpoints.

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ISSUES	ACTIONS
Evaluating the effectiveness of management options	
Knowledge of behavioral responses to different types of regulatory strategies.	Support research on behavioral responses to environmental policies.
Measuring effectiveness and estimating ecological outcomes of ecologically based pollution controls or restoration practices.	Support research to measure the effect of ecologically-based pollution controls on the fate of stressors in target environments.
	Support research examining the influence of key ecological restoration design parameters on the provision of ecological services at various scales.
Monitoring the performance of ecological restoration projects.	Develop and use both intensive and extensive monitoring designs to track the performance of ecological restoration projects.
Analyzing ecological changes	
Monitoring program design and ecological benefits assessment.	Evaluate the NAS recommendations for implementing ecological indicators.
Unknown relevance of current ecological monitoring programs to ecological benefits assessments.	Assess the relevance of current ecological monitoring programs to ecological benefits assessments.
	Recommend refinements of existing ecological monitoring programs and multi-metric indices.
Short duration and localized coverage of many monitoring programs.	Develop methods for using measures from short-duration and localized monitoring programs in ecological benefits assessments of long-term, large-scale actions.
	Encourage more investment in long-term, large-scale monitoring programs.
Ability to account for multiple stressors.	Develop case studies that characterize effects of “background” stressors on ecosystem responses to stressors targeted by Agency actions.
Ability to predict population-level responses to changes in environmental stressors.	Create a catalogue of existing population models and develop guidance for model selection and use.
	Expand integration of population and economic models for use in benefits assessment.
Data to predict population-level responses from individual-level effects.	Develop estimates of full stressor-response relationships on sub-lethal endpoints for more stressors.

ISSUES	ACTIONS
<p>1 Ability to predict changes in ecosystem</p> <p>2 processes in response to changing</p> <p>3 environmental stressors.</p>	<p>Identify which ecosystem processes are most important to benefits assessments at EPA.</p>
	<p>Identify which of the important ecosystem processes need further research to allow model development.</p>
	<p>Develop a catalogue of existing relevant ecosystem process models at different geographic scales to support benefits assessment.</p>
	<p>Expand portfolio of models to address the ecosystem processes important to benefits assessment at multiple geographic scales.</p>
	<p>Address data needs for those models.</p>
	<p>Evaluate other options for estimating changes in ecosystem processes.</p>
Estimating monetary values of ecological changes	
<p>5 Describing and measuring changes in the</p> <p>6 endpoints to be valued in stated and</p> <p>7 revealed preference studies of ecological</p> <p>8 resources.</p>	<p>Expand use of focus groups to identify relevant commodities and useful measures of them.</p>
	<p>Include ecologists in development of survey instruments.</p>
<p>9 Ability of surveys to elicit preferences</p> <p>10 from respondents.</p> <p>11</p>	<p>Expand use of focus groups and debriefing sessions to identify the boundaries of appropriate use for stated preference techniques.</p>
	<p>Expand use of combined revealed and stated preference methods.</p>
<p>12 Valuing changes in ecosystem services</p> <p>13 from changes in environmental stressors.</p> <p>14</p>	<p>Expand use of “production functions” for valuing ecosystem services.</p>
<p>15 Interactions between ecological changes</p> <p>16 and uses.</p>	<p>Expand use of linked ecological-economic models in ecological benefits assessments.</p>
<p>17 Using existing valuations studies for</p> <p>18 benefit transfer.</p>	<p>Encourage researchers to estimate values for a wider variety of ecological resources.</p>
	<p>Encourage researchers to use standardized measures of ecological resources in valuation studies.</p>

ISSUES	ACTIONS
	Encourage researchers to estimate and report values for a greater range of ecological changes.
	Support the development of new publication outlets.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32	Estimating ecological benefits from multiple values.
	Support research on methods for combining independent value estimates for benefit transfer.
Supplemental approaches	
Extending the use of risk-rating techniques to the evaluation of management alternatives.	Study the applicability of various rating and ranking procedures as a complement to BCAs.
Usefulness of ecological-economic systems approaches for EPA decision-making.	Evaluate the utility of selected ecological-economic systems properties for environmental decision support.
Establishing the linkages between ecological, economic, and social science methods in support of new valuation approaches.	Conduct trial applications of hybrid decision approaches in upcoming benefits assessments.

The issues and actions in the EBASP reflect an evaluation of the current state of the practice of ecological benefits assessment at EPA conducted by representatives of the Office of Policy, Economics and Innovation (OPEI), Office of Research and Development (ORD), and the major environmental program offices. The insights of the staff-level workgroup and management-level steering committee were augmented by information obtained through several information gathering exercises. These included a review of the relevant literature, a series of meetings within EPA and with other federal agencies, a survey of EPA risk assessors and managers, and input from EPA's Science Advisory Board (SAB). The strategic actions included in the EBASP reflect the workgroup's consensus as to which actions will most efficiently and effectively bridge gaps in the Agency's ability to conduct rigorous and comprehensive ecological benefits assessments on a routine basis.

Despite recognition of the need for improved capabilities in ecological benefits assessment across many program offices, EPA has not yet established an Agency-wide mechanism for addressing this need. To ensure continued progress, this Plan outlines three additional Agency-level actions to implement the EBASP: identify future ecology and economics research investment priorities, align resources to those priorities, and establish a forum to coordinate activities across the Agency and to sustain the effort to improve ecological benefits assessment over the long term. The EBASP does not prioritize actions for individual program offices; instead, each office will develop its own Action Plan

- 1 specifying projects and priorities appropriate to their programs, drawing from the EBASP to inform
- 2 their plans.

1 Introduction

Society benefits from both a healthy environment and a strong economy. Because of the increasingly difficult and complex trade-offs inherent in these and other competing social goals, the U.S. Environmental Protection Agency (EPA) recognizes the need to improve its ability to evaluate the benefits and costs of its policies and actions. Ecological benefits, which are the contributions to human well-being derived from ecosystems, are especially difficult to evaluate. The Agency developed this *Ecological Benefits Assessment Strategic Plan*, hereafter the EBASP or the “Plan”, to improve its ability to identify, quantify, and value the ecological benefits of its environmental policies and management actions² to provide decision-makers with a better basis for choosing among alternatives.

In principle, economic valuation methods convert benefits and costs of an environmental change into monetary terms. This makes it possible to express the net benefits of a policy or action – the benefits minus the costs – as a single number, which allows comparisons between any number of alternatives, including the status quo. In practice, however, current limits to our understanding of ecological and economic systems make it technically impossible to value all ecological benefits in monetary terms. Therefore, it is imperative that the Agency improve its ability to evaluate the ecological benefits of its activities in nonmonetary as well as monetary terms.

The EBASP is the most recent in a series of documents designed to improve the methods and data available for evaluating Agency policies and actions. In 1998, the Agency published its *Guidelines for Ecological Risk Assessment* (or *ERA Guidelines*, USEPA 1998a), which provide assistance to EPA analysts conducting ecological risk assessments. In 2000, the Agency published *Guidelines for Preparing Economic Analyses* (or *Economic Guidelines*, USEPA 2000a), an update and expansion of its *Guidelines for Performing Regulatory Impact Analyses* (or *RIA Guidelines*, USEPA 1983, 1991a), which provide assistance to EPA analysts conducting economic assessments of EPA activities. The *Economic Guidelines* incorporate recent advances in theoretical and applied work in environmental economics, but also acknowledge that the current state of the science is sometimes insufficient to accurately characterize many of the impacts of Agency actions or to value those impacts in monetary terms for comparison with expected costs. In 2002, EPA published A *Framework for the Economic Assessment of Ecological Benefits* (or *Ecological Benefits Framework*, USEPA 2002a), which draws from both the *ERA Guidelines* and the *Economic Guidelines* to provide assistance to EPA analysts conducting economic assessments of ecological benefits.

Implementation of these guidelines, however, requires appropriate methods, models, and data, many of which currently are unavailable for many types of environmental benefits. The complexity of ecosystems, economic systems, and the interactions between them creates substantial conceptual and

²Management action refers to any action due to an Agency rule, program, or project undertaken to ameliorate one or more known or suspected sources of stress to the environment.

1 technical difficulties for estimating ecological benefits in particular. Scientists and economists have been
2 investigating methods for evaluating ecological benefits for many years (e.g., Kneese et al. 1970,
3 Russell 1975), and much research in this area continues today (e.g., Milon and Shogren 1995, Perrings
4 et al. 1995, Swanson 1995, Dasgupta and Maler 2004). However, even when existing methods are
5 able, in principle, to value particular ecosystem services, it may not be feasible to implement them due
6 to both data and Agency resource limitations.

7
8 Much work still remains before accurate and comprehensive evaluations of the ecological
9 benefits of EPA activities can be performed on a routine basis. This need has been strongly articulated
10 across the Agency. During discussions for developing EPA's Environmental Economics Research
11 Strategy (EERS), one of the most strongly emphasized needs was for additional research bridging the
12 ecological-economic interface.

13
14 The remainder of this section specifies the goal and objectives of the EBASP and reviews the
15 role of benefits assessment in Agency decision-making. It also defines ecological benefits and related
16 terms and describes the intended audience and scope for the Plan. It concludes with an outline of the
17 EBASP.

18 19 20 **1.1 Goal and Objectives of the Plan**

21
22 The overall goal of the EBASP is to improve EPA's ability to identify, quantify, and value the
23 ecological impacts of its policies and actions to improve Agency decision-making. Specific objectives
24 of the Plan to achieve that goal are several:

- 25
26 • Clearly describe major technical and institutional issues that prevent the Agency from
27 conducting accurate and comprehensive ecological benefits assessments on a routine basis.
- 28
29 • Identify potential directions for future research, data collection, and development of analytical
30 tools.
- 31
32 • Propose activities to foster increased collaboration and coordination among the Agency's
33 ecologists, economists, and other analysts in conducting ecological benefits assessments.
- 34
35 • Propose institutional mechanisms to facilitate adaptive implementation of the EBASP, including
36 periodic adjustments of the Plan to reflect progress in the state of knowledge.
- 37

38 To achieve these objectives, the EBASP first describes the ecological and economic evaluation
39 approaches that EPA currently uses. The Plan then advocates a more integrated approach to assessing
40 ecological benefits that will require sustained interdisciplinary work among ecologists, economists, and
41 other analysts. The Plan then identifies key institutional and technical issues that currently limit the

Agency's ability to implement an integrated approach and describes Agency actions to ensure steady progress in addressing the issues. The Plan also specifies institutional actions to help the Agency implement the EBASP.

1.2 The Role of Benefits Assessment in Agency Decision-making

Virtually all government policies, including environmental policies, have both advantages and disadvantages. Benefit-cost analysis (BCA) is an approach for quantifying and comparing those advantages and disadvantages to help decision-makers make more informed choices about proposed policies or actions (Arrow et al. 1996). BCA estimates *net* benefits to society as a whole by comparing the expected benefits to those made better off by a policy or action with the expected costs imposed on those made worse off. BCA can be used both prospectively, to provide information to decision-makers for choosing among proposed alternative actions (e.g., USEPA 1987a,b,c, 2003a), and retrospectively, to determine whether an action was successful, to learn from any unintended consequences, or to determine whether further action is needed (e.g., USEPA 2001a). Benefits assessments are also useful for communicating to the public the value of EPA regulatory programs (USEPA 1991a, 2003b) and providing guidance for its voluntary programs (USEPA 2001a).

During regulatory development, the monetization of benefits might not be required, for example where Congress has legislated specific pre-determined environmental policy objectives. In fact, certain statutes prohibit consideration of benefit-cost information in regulatory decisions. Even if monetization is not required, the ecological effects of alternative policy options still need to be quantified to determine which policy meets the pre-determined environmental goals at the lowest cost. The current trend in environmental legislation, however, is to specifically require BCA as part of establishing environmental goals when implementing statutes. This emphasis on BCA can be seen in Executive Order 12866, the Safe Drinking Water Act (SDWA), and in some of the requirements of the Clean Air Act (CAA).

A complete BCA includes all categories of foreseeable benefits and costs associated with a policy or action under evaluation. The EBASP, however, focuses on only one potential part of a BCA – the assessment of ecological benefits – because this part can include some of the largest uncertainties in such analyses.

1.3 Focusing on Ecological Benefits

Broadly speaking, ecological benefits are contributions to human well-being derived from ecosystem goods and services (see Text Box 1 for definitions of these and related terms used

Text Box 1. Definition of ecological benefits and terms in the EBASP.

Ecological functions or processes^a are the characteristic physical, chemical, and biological activities that influence the flows, storage, and transformations of materials and energy within and through ecosystems, such as the uptake of nitrogen from soil by vegetation.

Ecosystem services^a are those ecological functions or processes that directly or indirectly contribute to human well-being or have the potential to do so in the future. Ecosystem services include:

- the provision of natural outputs enjoyed by people – sometimes referred to as **ecosystem goods** – such as wild game, fish, and forest products, as well as those attributes that provide amenity, such as a scenic vista.
- the processes that regulate and maintain the conditions necessary for human survival, such as nutrient cycling and aquifer recharge.

Ecological benefits^a describe the specific manner in which ecosystem services contribute to human well-being. In the EBASP, the term applies specifically to net improvements in human well-being that result from *changes* in ecosystem service flows attributable to some environmental management action. Examples of ecological benefits and their association with ecosystem services and management actions include the following:

- Increases in recreational opportunities and fish harvest resulting from actions that reduce the amount of biochemical oxygen demand in water bodies and increase fish populations.
- Expected improvements in human health resulting from present-day actions to protect biodiversity and thereby retain biological information useful to pharmaceutical research.
- Increases in the amount of drinking water available through aquifer recharge resulting from actions that reduce the areal extent of impervious surfaces covering a landscape.

Quantification is the expression of benefits in numerical units.

Valuation is the process of determining the worth, merit, or desirability of something. In the EBASP, the term is used more specifically to mean expressing the worth of a wide variety of environmental conditions in common units that can be aggregated and compared across alternative courses of action so that the relative desirability of the alternatives can be determined.

Monetization is the valuation in monetary (dollar) terms. Also "economic valuation" or "monetary valuation."

Ecological Risk Assessment^b is an evaluation of the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors.

Ecological Benefits Assessment is an evaluation of the expected ecological outcomes for society of environmental protection; outcomes are described qualitatively and are quantified in physical and monetary terms when possible.

Cost-effectiveness analysis is a comparison of the costs of policy actions in monetary terms with quantified outcomes or effects, usually expressed as ratios (e.g., dollars per acre of habitat protected).

Benefit-cost Analysis^c is a comparison of the benefits of policy actions with the associated costs of those actions, all expressed in monetary terms.

^aAdapted from Freeman (2003), Daily (1997, 2000), King (1997), and Whigham (1997).

Table 1. Types of ecological benefits categorized by benefits type.

Benefit Category		Explanation	Examples
Market		Generally relate to primary products that can be bought or sold as factors of production or final consumption products	<ul style="list-style-type: none"> • Food and water sources: commercial fish and livestock, game fish and wildlife, drinking water • Building materials: timber • Fuel: methane, fuelwood • Clothing: leather, fibers • Medicines: nature-derived pharmaceuticals
Non-market	Direct-use	Directly sought and used or enjoyed by society; include both consumptive uses and non-consumptive uses	<ul style="list-style-type: none"> • Consumptive recreational: fishing, hunting • Non-consumptive recreational: boating, swimming, camping, sunbathing, walking, climbing, birdwatching, sightseeing, enjoyment of visual amenities
	Indirect-use	Indirectly benefit society; may be valued because they support off-site ecological resources or maintain the biological and/or biochemical processes required for life support	<ul style="list-style-type: none"> • Maintenance of biodiversity • Maintenance and protection of habitat • Pollination of crops and natural vegetation • Dispersal of seeds • Protection of property from floods and storms • Water supply (e.g., ground-water recharge) • Water purification • Pest and pathogen control • Energy and nutrient exchange
	Non-use	Benefit does not depend on current use or indirect benefits; individuals might value the resource without ever intending to use it or might have a sense of environmental stewardship; includes bequest value, existence value, and cultural/historic value	<ul style="list-style-type: none"> • Perpetuation of an endangered species • Wilderness areas set-aside for future generations

Sources: USEPA (2000b, 2002a), Principe (1995), and Daily et al. (1997).

throughout the EBASP). Policies for environmental protection may discourage or restrict activities that are harmful to the environment, may encourage or require activities to restore damaged ecosystems, or may combine these approaches. The ecological benefits of such policies depend on how they influence the behavior of individuals, households, and firms, which in turn affect the flows of ecosystem goods and services enjoyed by society at large. Table 1 lists examples of ecosystem goods and services from the larger universe of well recognized ecological benefits that flow from healthy ecosystems. The examples in Table 1 are categorized according to the types of economic benefits they provide: market or non-market, and direct-use, indirect-use, or non-use.

The EBASP focuses on estimating the value of changes in ecosystem goods and services that result from EPA actions. In this document, "ecological benefits assessment" refers to both the quantification of relevant ecological outcomes and, to the extent possible, the measurement of those

1 outcomes in monetary or other terms of social value. A benefits assessment may also include qualitative
2 descriptions of ecological outcomes. Because changes in human well-being are difficult to quantify
3 directly, EPA considers changes in the condition of ecosystems *per se* to be ecological benefits when
4 the relationship between ecosystem condition and human well-being is conceptually evident.

5
6 When the expected benefits of a policy are obvious to all concerned, few will debate the
7 appropriate course of action. When the expected benefits are not so obvious, quantifying and
8 monetizing ecological benefits can play a important role in determining the best course of action, in
9 communicating the rationale for taking action, and in building consensus by providing more information
10 about the advantages and disadvantages of the alternatives.

11
12 Finally, note that in the EBASP, the term “ecological benefits” refers to the *net* ecological
13 benefits of an EPA action, considering any negative as well as positive changes in ecological services
14 that might result. Also note that the phrase “ecosystem goods and services” is sometimes used in the
15 Plan, although “ecosystem services”, as defined in Text Box 1, includes ecosystem goods.

16 17 18 **1.4 Intended Audience and Scope of This Plan**

19
20 The primary audience for the EBASP includes Agency managers and analysts who devote time
21 or other resources toward basic or applied research in the areas of ecology, related natural sciences,
22 and economics relevant to ecological benefits assessment. The discussion of the integrated ecological
23 benefits assessment process is intended to provide analysts with a general conceptual framework for
24 conducting assessments; more detailed guidance can be found in the *Ecological Benefits Framework*,
25 the *ERA Guidelines*, and the *Economic Guidelines*. The discussions of institutional issues and actions
26 the Agency can take to address them should help managers to improve coordination across EPA
27 offices, to provide opportunities for analysts to collaborate in interdisciplinary teams exploring
28 ecological benefits of Agency actions, and to foster true interdisciplinary conduct of ecological benefits
29 assessments. The discussions of technical issues and actions to address them should assist Agency
30 managers in allocating resources toward research and other activities that will improve the Agency’s
31 overall benefits assessment capabilities. Those discussions also will assist analysts in generating ideas
32 on specific research projects in those areas. The actions described in the EBASP also will help EPA
33 offices to develop their own Action Plans to guide their future investments in ecological benefits
34 assessment. Finally, although this Plan targets primarily an internal EPA audience, researchers in
35 academia and other federal agencies and interested members of the public may find it useful for
36 understanding EPA’s needs and objectives in this area.

37
38 The EBASP focuses on institutional and technical issues that most often arise in national-level
39 ecological benefits assessments, where the statutory requirements for BCA most often apply. EPA
40 Headquarters is largely responsible for developing and evaluating Agency regulations that apply
41 nationwide; therefore, the EBASP is primarily intended for managers and analysts in EPA headquarters,

1 rather than regional offices. However, the methods and the research needs for ecological benefits
2 assessments discussed here may be relevant for EPA regional offices as well.

3
4 Finally, the EBASP focuses on issues at the nexus of ecological and economic analyses that are
5 specific to ecological benefits assessments. The EBASP does not address many of the more general
6 research needs in either ecology or economics or those that apply to ecological or economic
7 assessments conducted independently.

10 **1.5 Organization of the EBASP**

11
12 The remainder of the EBASP is organized in five sections. To provide background and
13 context, Section 2 describes the nature of the challenge facing EPA and provides background on
14 previous and ongoing Agency activities in this area. After describing the current state of the practice for
15 assessing ecological benefits using standard ecological and economic approaches, Section 3 describes
16 and calls for an integrated interdisciplinary approach to ecological benefits assessment. Section 4 lays
17 out the strategic actions of this Plan. It describes institutional and technical issues that prevent the
18 Agency from conducting accurate and comprehensive ecological benefits assessments on a more
19 routine basis and describes Agency actions to address those issues. The actions indicate potential
20 institutional changes and directions for future research, data collection, and development of analytical
21 tools that will improve ecological benefits assessments at the Agency. Section 5 provides an
22 implementation plan for the EBASP. References are provided in Section 6.

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2 Background

Assessing the broad variety of ecological benefits potentially affected by EPA decisions is complex and challenging for several reasons. First, despite significant advances in understanding ecosystem services and the natural processes that provide them, knowledge of these very complex systems remains incomplete. Ecologists regularly confront problems in estimating the probable range of effects of proposed policies on ecological systems, in part because the interactions between species and their environments are not well understood. Likewise, economists regularly confront problems in estimating the benefits of proposed policies, in part because values for ecological resources are very difficult to estimate, particularly when the effects of policy changes cannot be clearly articulated. Furthermore, the data and methods needed for a given assessment are often limited as well. Technical challenges to integrating ecological and economic models further complicate benefits assessment, as little progress has been made in synthesizing these disciplines' analytical approaches. An additional challenge has been the lack of consensus between scientists, government agencies, and the public on the desired state of natural resources, and the resulting lack of benchmarks for assessing policy outcomes. Historical and practical impediments to collaboration between ecologists and economists in conducting ecological benefits assessments also stem from institutional characteristics of the Agency. For instance, Agency resources are limited and not always available for ecological benefits assessments, particularly in cases where they are not required by executive order or statute.

In recent years, EPA, other federal agencies, and a number of non-governmental organizations have participated in collaborative efforts designed to improve the state of the science and practice in ecological benefits assessment. These efforts include original research, workshops and symposia, case studies, meetings between organizations, and the development of guidance for Agency staff. The *Ecological Benefits Assessment Strategic Plan* (EBASP or "the Plan") builds on these past and current efforts by identifying institutional changes and actions to advance the Agency's capabilities in assessing ecological benefits. This section briefly describes the nature of the challenge before EPA (Section 2.1), some of the past (Section 2.2) and current (Section 2.3) efforts in this area, and the key features of this Plan that distinguish it from these other efforts (Section 2.4).

2.1 Nature of the Challenge

Figure 1 illustrates how the assessment of ecological benefits (which includes both the ecological and economic components) is limited by the abilities of analysts to fully identify, quantify, and value changes in ecological goods and services. During the problem formulation stage of an assessment, some benefits may not be recognized, because many complex ecosystems and their interactions with economic systems are not completely understood. During the ecological stage of the assessment, some benefits may not be quantified, and during the economic stage of the assessment, some quantified benefits may not be monetized, because of methodological and data limitations specific

to each discipline. Identified (but unquantified) and quantified (but unmonetized) benefits should still be presented to decision-makers, but it may be difficult to appropriately interpret and synthesize this information when deciding among policy options. The EBASP is intended to help reduce the “diversions” in Figure 1 of unrecognized, unquantified, and unmonetized goods and services in order to improve both the accuracy and completeness of ecological benefits assessments at EPA.

As mentioned in Section 1, one of the reasons why data and methods are not always available for ecological benefits assessments is because historically there was little need to conduct such assessments. When the Agency conducted BCAs, the benefits assessment often focused exclusively on human health effects and, in many cases, human health benefits outweighed the costs of the regulation. Hence, EPA’s regulatory and programmatic BCAs have included few categories of ecological benefits. In other words, the impetus to study complex ecological systems and to estimate the value of changes in these systems to society in a regulatory context did not arise until recently. It is now apparent that additional information is needed to support EPA in evaluating increasingly complex tradeoffs in environmental protection.

In its report *The Benefits and Costs of the Clean Air Act: 1990 to 2010* (USEPA 1999), the Agency presented an extensive assessment of the outcomes of regulations that addressed many sources of air pollution. The assessment was supported by independent panels of physical and social scientists and public health experts who provided commentary and advice throughout the study's design, implementation, and documentation. The study also was subject to extensive peer review. Under the Clean Air Act (CAA), EPA established regulations that set maximum ambient air quality levels. These targeted several types of pollutants, which are listed in Table 2.

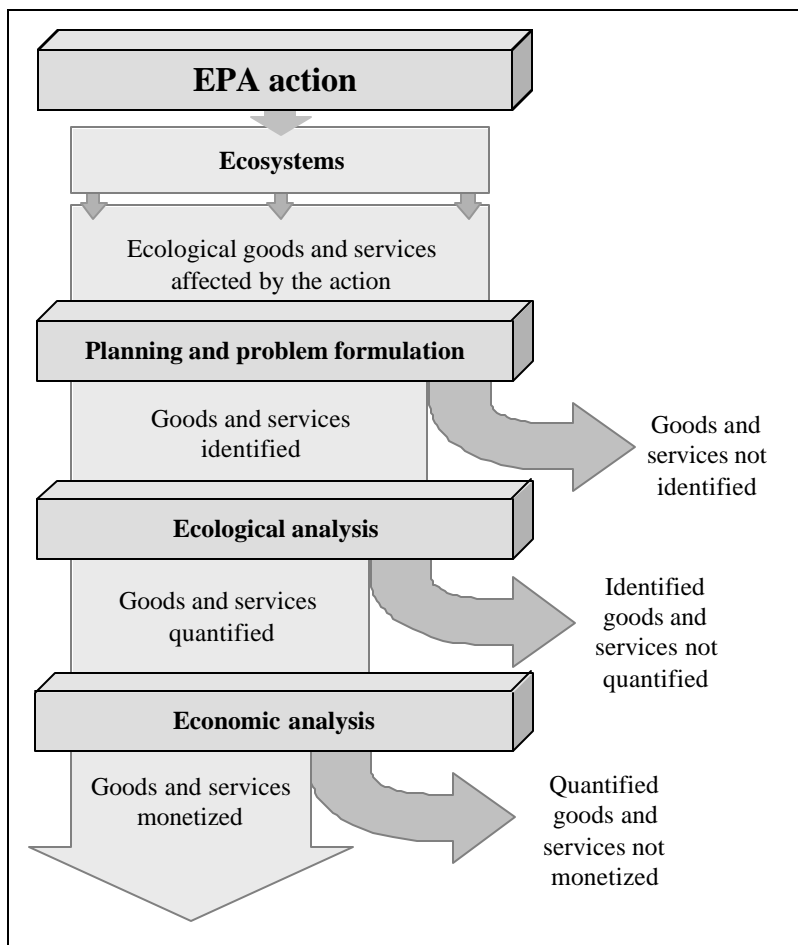


Figure 1. Representation of the benefits assessment process indicating where some ecological benefits may remain unrecognized, unquantified, or unmonetized.

Table 2. Ecological benefits of reductions in air pollutants identified in the analysis of the Clean Air Act.

Pollutant reduced	Ecological benefits identified	Quantified?	Monetized?
Particulate matter	Improved visibility at national parks	YES	YES
Acidic deposition	Improved recreational freshwater fishing	YES	YES ^a
	Increased productivity of commercial forests (e.g., timber, non-timber forest products)	no	no
	Improved commercial freshwater fishing	no	no
	Reduced watershed damages (e.g., improved water filtration and flood control)	no	no
	Improved recreational amenities in terrestrial ecosystems (e.g., forest aesthetics, nature study)	no	no
	Maintained existence value and option values for ecosystems impacted by acid deposition	no	no
Nitrogen deposition	Reduced nitrogen deposition for eastern estuaries	YES	no
	Increased productivity of commercial fishing, decreased productivity of agriculture and forests	no	no
	Reduced watershed damages (e.g., improved water filtration and flood control)	no	no
	Improved recreation in estuarine ecosystems (e.g., recreational fishing, aesthetics, nature study)	no	no
	Maintained existence value and option values for ecosystems impacted by nitrogen deposition	no	no
Tropospheric ozone	Increased commercial timber yields ^b	YES	YES
	Increased tons of carbon sequestered in forests	YES	no
	Increased agricultural yields ^c	YES	YES
	Improved recreational amenities in terrestrial ecosystems (e.g., forest aesthetics, nature study)	no	no
	Maintained existence value and option values for ecosystems impacted by ozone	no	no
Hazardous air pollutants (HAPs) deposition	Improved commercial and recreational fishing	no	no
	Maintained existence value and option values for ecosystems impacted by HAPs (e.g., biodiversity values)	no	no

Source: USEPA (1999), Adapted from Tables 7-5 and 7-11.

^aAnalysis was restricted to the Adirondacks.

^bAnalysis was restricted to a limited set of timber species.

^cAnalysis was restricted to a limited set of agricultural crops.

Analysts developed conceptual models of the linkages between reductions in those pollutants and a number of ecological benefits (Table 2). A more comprehensive list of ecological benefits can be found in Appendix E of the report (USEPA 1999). Given the number of pollutants, their wide atmospheric dispersal across the United States, the number of ecosystems impacted, and the complexity of the ecosystems, however, it is likely that other positive ecological outcomes of pollution reduction were not recognized.

To assess the effect of regulations under the CAA, analysts needed to assess the effectiveness of EPA actions in achieving reductions of atmospheric pollutants. Control technologies and emission limits specified in EPA's CAA regulations have several directly measurable effects, but other effects are more difficult to measure and often must be estimated instead. Reductions in ambient concentrations of pollutants over particular ecological systems, including water bodies, forests, and agricultural areas, need to be predicted from estimated reductions in emissions. In addition, analysts also need to estimate the deposition of air pollutants into water and soil and transport through food chains. Ambient concentrations of some pollutants are direct measures of some ecological benefits, such as visibility at national parks. For most pollutants and ecological benefits, however, the relationship between pollutant concentrations and ecological goods and services is indirect. For example, analysts would first need to estimate how reductions in atmospheric pollutants might affect timber and crop growth or fish and wildlife populations before they could value the resulting ecological benefits. Only if ecological changes can be quantified can EPA attempt to estimate the value of those changes to society. Analysts can value commercial products, such as agricultural commodities or timber, at market prices and can value some of the benefits from increased populations of sport fish or improvements in fishing conditions via their contribution to recreational activities. Improved visibility at national parks increase people's willingness to pay for trips, to undertake them, or to take them more frequently. Estimating the value of recreational activities, however, is complicated and typically requires extensive surveys. Even well-designed surveys may prove to be uninformative.

The third column of Table 2 indicates those benefits of regulations under the CAA that analysts were able to quantify in physical units, such as additional tons of timber per acre harvested or additional number of days of clear viewing at national parks. For example, analysts were able to estimate the relationship between reductions in ozone and increased timber growth. On the other hand, due to data limitations, analysts were unable to quantify the relationship between reduced acid deposition and timber growth. Of those benefits that were quantified, even fewer could be measured in monetary terms, as shown in the last column of Table 2. Analysts valued timber at its market price and used recreational demand models to value benefits like improved visibility. However, analysts could not monetize the benefits of reduced nitrogen deposition or increased carbon sequestration, in part because the relationships between those changes and goods and services that people readily value are not direct. Were it possible to quantitatively link reduced nitrogen deposition in surface waters to changes

1 in populations of commercial fish species, some portion of the value of that outcome might have been
2 measurable in dollars.

3
4 The CAA benefits assessment experience illustrates some of the challenges of determining the
5 effect of EPA policies and actions on ecological outcomes and benefits. If plausible connections
6 between emission sources and ecological changes cannot be quantified, the outcome of the action
7 cannot be estimated in physical or dollar terms. Estimating the relationships between changes in
8 emissions and changes in ecosystems, their services, and the value of those services, requires
9 appropriate ecological data and valuation studies, much of which currently is not readily available.
10 Traditionally, ecologists at EPA have focused primarily on the assessment of risks, while economists
11 have focused primarily on the assessment of costs and benefits of regulations. Increased collaboration
12 between EPA ecologists and economists is needed to improve benefits assessments at the Agency.
13 Increased collaboration increases the likelihood that important ecological effects are properly identified,
14 quantified, and used as inputs into economic valuation models to the extent possible given available data
15 and analytical tools. The collaboration also helps to identify interdisciplinary information and analytic
16 needs, as was done in the development of the EBASP.

17 18 19 **2.2 Past EPA and Other Efforts**

20
21 In 1981, the President issued Executive Order 12291, which directed federal agencies to
22 assess the costs, benefits, and economic impacts of their major regulations and established a formal
23 review process by the Office of Management and Budget (OMB). To assist Agency analysts in
24 meeting OMB requirements, EPA issued its *Guidelines for Performing Regulatory Impact Analyses*
25 (or *RIA Guidelines*, USEPA 1983), which provide a brief description of what was required for
26 assessing costs, benefits, and economic impacts of Agency policies and actions. The *RIA Guidelines*
27 were updated in 1991 with several appendices including the *Analysis of Benefits*, which provide
28 general recommendations on methods of estimating benefits in several categories, including human
29 health; agriculture, fisheries, and silviculture; materials; recreation; aesthetics; and ecosystems (USEPA
30 1991a). For the latter category, the *RIA Guidelines* acknowledge that “estimating the benefits (or
31 damages averted) of environmental regulations that affect ecosystems is perhaps the most complex
32 problem in benefits analysis” (pg A-19). The *RIA Guidelines* further note that many ecosystem service
33 flows may not be apparent, are difficult to understand, and are difficult to measure with conventional
34 economic methods (pg A-20).

35
36 Some offices within EPA developed more detailed guidance to help staff conduct economic
37 valuations of at least some ecological changes. For example, in 1990, the Office of Marine and
38 Estuarine Protection (OMEP) and the Office of Policy, Planning, and Evaluation (OPPE) published *The*
39 *Economics of Improved Estuarine Water Quality: An NEP [National Estuary Program] Manual*
40 *for Measuring Benefits* (USEPA 1990a). This manual provides guidance on using some fairly
41 well-developed valuation techniques to monetize ecological benefits such as recreational swimming,
42 fishing, and boating and commercial fishing benefits. At the same time, the Office of Policy Analysis

(OPA) was supporting the development of techniques for estimating economic values for a wider range of ecosystem services, including many that typically are overlooked such as pest and disease control, pollination, microclimate control, and nutrient cycling (draft final report *Ecosystem Services and Their Valuation*, USEPA 1990b).

In its 1990 report *Reducing Risk: Setting Priorities and Strategies for Environmental Protection*, the EPA Science Advisory Board (SAB) stated that the value of natural ecosystems was inadequately considered in setting priorities at EPA and insufficient for EPA decision-making in general (USEPA 1990c). The SAB identified two key problems: (1) the focus of current economic models on structural attributes of ecosystems rather than ecosystem functions and relationships, and (2) the fact that current ecological models generally do not describe the “services” of ecosystems. In that report, the SAB recommended that EPA “develop improved analytical methods to value natural resources and to account for long-term environmental effects in its economic analyses” (USEPA 1990c).

Partly in response to SAB’s recommendations, OPPE established an Ecosystem Valuation Forum in 1990. A key purpose of the Forum was to assist EPA “in overcoming piecemeal approaches to incorporating ecosystem values into a benefit/cost framework” at the Agency (Brody and Kealy 1995, pg 67). Its objectives were to improve existing methods as well as to develop new methods for valuing ecosystem services. During 1991 and 1992, the Forum met in a series of public workshops and identified many challenges to valuing ecosystem services, including the limited understanding of the many complex relationships between ecosystems and human well-being. The outcome of this effort was published in a special issue of *Ecological Economics* (1995, Vol. 14) and recommended that economists and ecologists collaborate on additional case studies as a next step in the process of improving ecological benefits assessments. Changing priorities and Agency reorganizations led to the discontinuation of the Ecosystem Valuation Forum.

The issuance of Executive Order 12866 on regulatory planning and review in 1992 reaffirmed requirements for the analysis of social benefits and costs for significant regulatory actions. In addition to those requirements, economic assessments are also called for under various administrative statutes (e.g., *Unfunded Mandates Reform Act of 1995*). Recognizing the importance of high quality economic analysis, in 2000, OMB released its *Guidelines to Standardize Measures of Costs and Benefits and the Format of Accounting Statements* (or *OMB Guidelines*, USOMB 2000).

In 2000, EPA significantly updated and revised its *RIA Guidelines* by publishing the *Guidelines for Preparing Economic Analyses* (or *Economic Guidelines*, USEPA 2000a). The *Economic Guidelines* incorporate the advancements in techniques for benefits estimation, different economic models for assessing costs and other effects, and the greatly expanded data sources and related guidance materials developed since 1983. With respect to ecological benefits, the *Economic Guidelines* provide a categorization scheme based on how directly benefits are experienced by the public and how the benefits relate to the private good/public good continuum. That categorization is intended to help analysts identify which monetary valuation techniques are applicable in different situations. The *Economic Guidelines* implicitly assume that the necessary quantitative information on

1 changes in ecological conditions, processes, and service flows can be provided by ecologists or other
2 scientists. As discussed in Sections 2.1 and 4.5 of this Plan, that assumption is not always valid.

3
4 In 2000, the SAB published *Toward Integrated Environmental Decision-Making*, a follow-
5 up to its 1990 *Reducing Risk* report, which provided a conceptual vision for “the next step” in
6 environmental protection for the United States (USEPA 2000c). The report describes some important
7 considerations for public environmental decision-making and the need for broad participation in the
8 decision-making process. The SAB recommended that “when evaluating risk reduction options, EPA
9 should strive to weigh the full range of advantages and disadvantages, both those measured in dollars as
10 costs and benefits and those for which there may not be a comprehensive dollar measure, such as
11 sustainability and equity” (USEPA 2000c, pg 39, Recommendation 5). The SAB further
12 recommended that “EPA should seek and develop methods to characterize public values and
13 incorporate those values into goal-setting and decision-making” (USEPA 2000c, pg 40,
14 Recommendation 6).

15
16 As a step toward implementing this recommendation, EPA sponsored a public workshop,
17 *Understanding Public Values and Attitudes Related to Ecological Risk Management*, which
18 brought together experts from ecology and four behavioral sciences – economics, psychology, decision
19 science, and anthropology – to consider a specific case study (USEPA 2001b). The case study chosen
20 for evaluation was nitrogen deposition in Tampa Bay, because the ecological services data necessary to
21 support economic valuation already existed. The centerpiece of the workshop was a series of
22 presentations on research approaches to assess public environmental values associated with the Bay.
23 The workshop took an introductory step toward implementing one of the suggestions in the SAB report
24 *Toward Integrated Environmental Decision Making* by creating a forum for open discussion on the
25 topic of natural resource valuation. The workshop affirmed that the goal of understanding public values
26 requires the use of social science approaches, which must be selected according to context and fully
27 integrated with the environmental science of the valuation problem.

28
29 In 2002, EPA published *A Framework for the Economic Assessment of Ecological*
30 *Benefits* (or *Ecological Benefits Framework*, USEPA 2002a), which was developed by an EPA
31 Science Policy Council workgroup. The *Ecological Benefits Framework* outlines a process by which
32 ecologists and economists can conduct and coordinate an ecological benefits assessment. The steps of
33 an economic benefits analysis, as identified in the *Economic Guidelines*, are matched and associated
34 with the steps of an ecological risk assessment as outlined in EPA’s *Guidelines for Ecological Risk*
35 *Assessment* (or *ERA Guidelines*, USEPA 1998a). The *Ecological Benefits Framework* describes a
36 process for conducting assessments of ecological benefits that assumes the necessary methods,
37 models, and data are available. Because gaps exist in the state of knowledge and available assessment
38 tools, implementation of the *Ecological Benefits Framework* in many cases will require the
39 development of new tools and data to overcome the gaps. Furthermore, implementing the *Framework*
40 requires that ecological risk assessments provide all of the necessary information for a benefits
41 assessment. However, risk assessments and benefits assessments are often conducted for different

purposes, so in many cases additional ecological analyses will be required to provide all of the necessary information for a benefits assessment.

In 2003, EPA's Office of Research and Development (ORD) published *Integrating Ecological Risk Assessment and Economic Analysis in Watersheds: A Conceptual Approach and Three Case Studies* (USEPA 2003c), which describes ecological risk assessments conducted in three watersheds, followed by economic analyses. The report discusses the successes and shortcomings of attempts to integrate the ecological and economic analyses for each watershed, and it recommends a conceptual approach for integration that could be used in future watershed management efforts. This conceptual approach is similar to that laid out in the *Ecological Benefits Framework*, except that it addresses the support of site-specific (as opposed to national) decision-making and is not limited to the BCA context.

Other federal agencies also have been addressing the challenge of valuing ecological benefits (e.g., NMFS 2000; USACE 1995, 1996, 2003; USDA 1999, 2002; USDOE 1995; USFWS 1985, 1995). For example, in 2001, the U.S. Army Corps of Engineers (ACE) sponsored a workshop on *Improving Environmental Benefits Estimation*, which included representatives from EPA and several other federal agencies. The workshop was part of their overall strategy for improving environmental benefits estimation in their assessments of ecological restoration and multi-purpose projects. One of ACE's goals in holding the interagency workshop was to encourage multi-agency participation in the strategy. ACE has developed a white paper, *Improving Environmental Benefits Analysis*, articulating its strategy (USACE 2003). ACE recognizes that before it can value many of the ecological benefits resulting from its projects, it must invest in long-term research efforts and policy development.

In its revised guidelines for regulatory analysis, *Informing Regulatory Decisions: 2003 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local and Tribal Entities* (USOMB 2003), OMB discusses ecological benefits in a section entitled *Benefits and Costs that are Difficult to Quantify*. OMB recommends that in BCAs, analysts should not only present monetized benefits, but should also present any relevant quantitative information and descriptions of unquantified ecological effects.

2.3 Ongoing EPA Efforts

There currently are a number of ongoing EPA activities and initiatives aimed at improving valuation of ecological benefits. In 2003, the SAB convened a *Panel on Valuing the Protection of Ecological Systems and Services*. The purpose of the Panel is "to provide advice to strengthen the EPA's approaches for assessing the costs and benefits of actions designed to protect ecological systems and services, to identify research needs to improve how ecological resources are valued, and to

1 support decision-making to protect ecological resources.”³ In addition, the SAB Council, which
2 advises EPA on its assessments of the benefits and costs of the CAA, has formed an Ecological Effects
3 Subcommittee to guide EPA in quantifying additional ecological benefit categories.
4

5 EPA's National Center for Environmental Research (NCER) and National Center for
6 Environmental Economics (NCEE) have recently released their draft *EPA Environmental Economics*
7 *Research Strategy* (EERS) (USEPA 2003d). The EERS identifies EPA's highest priority research
8 needs in environmental economics, describes the short- and long-term research objectives for each
9 need, describes the resources and tools needed to achieve those objectives, and suggests a time frame
10 for meeting the objectives. The EERS was developed in cooperation with EPA's program and regional
11 offices. Interviews conducted to identify top priorities for the EERS revealed ecological benefits
12 valuation as one of the areas of greatest need. Research is needed that can reduce the uncertainty
13 associated with the large number of ecosystem benefits that are not valued and that can help economists
14 to more fully understand how people consider and value ecological services. The EBASP
15 complements the EERS by providing more detailed research needs in ecological valuation, which
16 NCER and NCEE can use to guide and focus their research.
17

18 Through ORD's Science To Achieve Results (STAR) grants program and other research
19 mechanisms, NCER is continuing to support research through the Valuation for Environmental Policy⁴
20 grants program, as well as a number of other areas that have the potential to advance methods and data
21 for conducting ecological benefits assessment.⁵ Recent solicitations for grants have requested research
22 on ecological classification, monitoring, and indicators, and have frequently focused on aquatic
23 resources. The EBASP will assist ORD in defining key research areas related to ecological benefits
24 valuation.
25

26 NCEE and the Office of Water (OW), with the U.S. Department of Agriculture (USDA) and
27 the U.S. Department of the Army, are cosponsoring a National Research Council (NRC) project on
28 *Assessing and Valuing the Services of Aquatic Ecosystems*.⁶ The NRC committee of academic
29 experts is charged with evaluating methods for assessing services and the associated economic values
30 of aquatic and related terrestrial ecosystems. The project focuses on “identifying and assessing existing
31 economic methods to quantitatively determine the intrinsic value of these ecosystems in support of
32 improved environmental decision-making, including situations where ecosystem services can be only
33 partially valued” (NRC 2004).
34

³ <http://www.epa.gov/sab/panels/vpesspanel.html>

⁴ Prior to 2003, this was known as the *Decision-making and Valuation for Environmental Policy* program.

⁵ <http://cfpub.epa.gov/ncer/abstracts/index.cfm/fuseaction/research.search/rpt/abs/type/3>

⁶ <http://www4.nas.edu/cp.nsf/Projects%20by%20PIN/WSTB-U-00-02-A?OpenDocument>

1 These ongoing efforts demonstrate that EPA and other agencies consider improving ecological
2 benefits assessment to be very important for improving regulatory impact analyses. Both EPA's SAB
3 and the National Academy of Sciences (NAS) are actively working to provide advice, leverage existing
4 information, and identify research needs to enable adequate consideration of ecological benefits in
5 environmental decision-making.

6 7 8 **2.4 This Effort and Looking Forward**

9
10 Many of the activities described above were initiated and conducted as independent actions in
11 specific EPA offices, with expectations for next steps and procedures for implementation largely
12 undocumented; therefore, follow-up activities often did not occur. Although the past and ongoing
13 activities described in the preceding sections clearly indicate the need for improved capabilities in
14 ecological benefits assessment across many EPA offices, EPA has not yet established an Agency-wide
15 forum for addressing this need. For example, due to shifting Agency priorities and reorganization of the
16 single sponsoring office, the Ecosystem Valuation Forum was short-lived, and therefore could not serve
17 to guide the Agency along a sustained and organized effort. Furthermore, some past and ongoing
18 activities seem to focus on economic methods exclusively.

19
20 The EBASP is intended to improve this situation by laying out a roadmap for a series of
21 incremental research efforts and institutional changes across EPA that will help the Agency steadily
22 improve its ability to identify, quantify, value, and communicate the ecological benefits of its
23 environmental policies and management actions. The Plan recognizes that past efforts have been
24 valuable, but also that much work remains to be done. The EBASP distinguishes itself from previous
25 and other current efforts by considering the full scope of the practice of ecological benefits assessment
26 at EPA (Section 3.1), by describing and advocating an interdisciplinary approach to ecological benefits
27 assessment (Section 3.2), and by suggesting research activities (Sections 4.3 through 4.7) and
28 institutional changes (Sections 4.2 and 5) that will improve the Agency's capabilities in this area. The
29 EBASP also provides an implementation strategy by identifying the points in EPA's research budgeting
30 processes that need to be targeted and the oversight activities that are needed to ensure a sustained
31 effort (Section 5).

3 Linking Ecological and Economic Assessments

This section describes key challenges that analysts face when attempting to assess ecological benefits of EPA actions. Section 3.1 describes the current state of Agency practices in ecological and economic assessment of environmental policies or management actions. As indicated in Section 1, management action refers to any action due to an Agency rule, program, or project undertaken to ameliorate one or more known or suspected sources of stress to the environment. Ecological and economic assessments generally have been pursued independently. Section 3.2 advocates an integrated ecological benefits assessment process, based in part on *A Framework for the Economic Assessment of Ecological Benefits* (or *Ecological Benefits Framework*, USEPA 2002a). That section provides the foundation for Section 4, which discusses some of the specific issues that stand between the current practices and the integrated process outlined below and which presents recommendations to address those issues.

3.1 Current State of the Practice

Over the past few decades, the Agency has made substantial progress in providing guidance and tools for conducting ecological and economic assessments, particularly with regard to ecological risk assessments and benefit-cost analyses (BCAs) (see Section 2.2). However, ecological risk assessments are designed to address different questions than those posed by ecological benefits assessments, and therefore risk assessment results are rarely sufficient for a thorough benefits assessment. In addition, benefits assessments at the Agency generally have been the responsibility of economists, with limited input from the ecological sciences; the need for more interdisciplinary benefits assessments has only recently been articulated in the *Ecological Benefits Framework* (USEPA 2002a) and in *Integrating Ecological Risk Assessment and Economic Analysis in Watersheds: A Conceptual Approach and Three Case Studies* (USEPA 2003c).

Agency assessments begin, implicitly or explicitly, with a planning phase or dialogue in which risk managers, stakeholders, and risk and benefit assessors identify management goals, the types of analyses required, and the scope of those analyses. Ideally, all of these individuals and others (e.g., analysts and consultants from a variety of disciplines) will remain involved throughout the assessment process. In the following discussions, however, we focus only on ecological and economic disciplines and advocate their better integration to produce more comprehensive ecological benefits assessments on a routine basis.

3.1.1 Ecological Assessments

Ecological assessments at EPA take many forms depending on the legislative mandates and decisions that they support. The forms include prospective risk assessments to evaluate environmental

management options (e.g., for a proposed waste site or registration of a pesticide) and retrospective assessments of ecological impacts to diagnose their causes and to evaluate mitigation options. Also included are assessments of ecological responses to stressors (e.g., toxic substances) to support development of environmental quality criteria and assessments of environment monitoring data to document the condition of the nation's ecosystems. In conducting ecological risk assessments, the Agency generally follows the principles outlined in its *Guidelines for Ecological Risk Assessment* (or *ERA Guidelines*, USEPA 1998a).

In conjunction with many other factors, ecological risk assessment plays an important role in Agency decisions. Ecological risk assessment is a process "used to understand and predict the relationships between stressors and ecological effects in a way that is useful for environmental decision making" (USEPA 1998a, pg 1). Figure 2 shows a stylized representation of a standard ecological risk assessment at the Agency. This figure is consistent with the representation in the *ERA Guidelines* (USEPA 1998a), but it has been generalized and simplified to focus on the key similarities and differences between ecological assessments and economic benefits assessments, which are depicted later in Figure 3. The shaded box contains the stages of the assessment itself; the rounded box illustrates how ecological knowledge, methods, models, and data inform each stage, as depicted by the arrows.

Problem formulation, the first stage in ecological risk assessment, begins with information from the planning dialogue and includes several activities. Analysts determine the context and scope of the assessment, identify likely stressors and exposure pathways, and select *assessment endpoints* (USEPA 1998a). Assessment endpoints are the ecological entities and their attributes that have a clear relationship with risk management goals (USEPA 1998a, 2003e). Examples of such endpoints are trout abundance and richness of species in the fish community. Analysts then develop a *conceptual model* of the system in which they link the stressors to the endpoints via direct and indirect pathways, considering also the effects of other co-occurring stressors. Problem formulation concludes with the development of an *analysis plan* specifying the data and methods that analysts will use to assess ecological risk.

The remainder of the ecological risk assessment involves analysis of ecological exposures and responses to exposure (effects) and characterization of risks to (or effects on) the assessment endpoints. Analysis of exposure entails an evaluation of the magnitude of co-occurrence of stressors and ecosystem components (e.g., populations, communities) over time and space. Analysis of ecological effects requires development of stressor-response profiles that describe the likely responses of those ecosystem components to such exposures. Analysis of effects generally is based on published data from laboratory and field experiments or observational studies of the same or similar stressors on similar ecosystem components. Risk characterization integrates the exposure and effects assessments to estimate the potential for adverse effects on the assessment endpoints. Ecological risks are communicated to the decision-makers together with interpretation of the significance of the risks and possibly recommendations for actions to mitigate effects and/or assessments of the effectiveness of different mitigation actions.

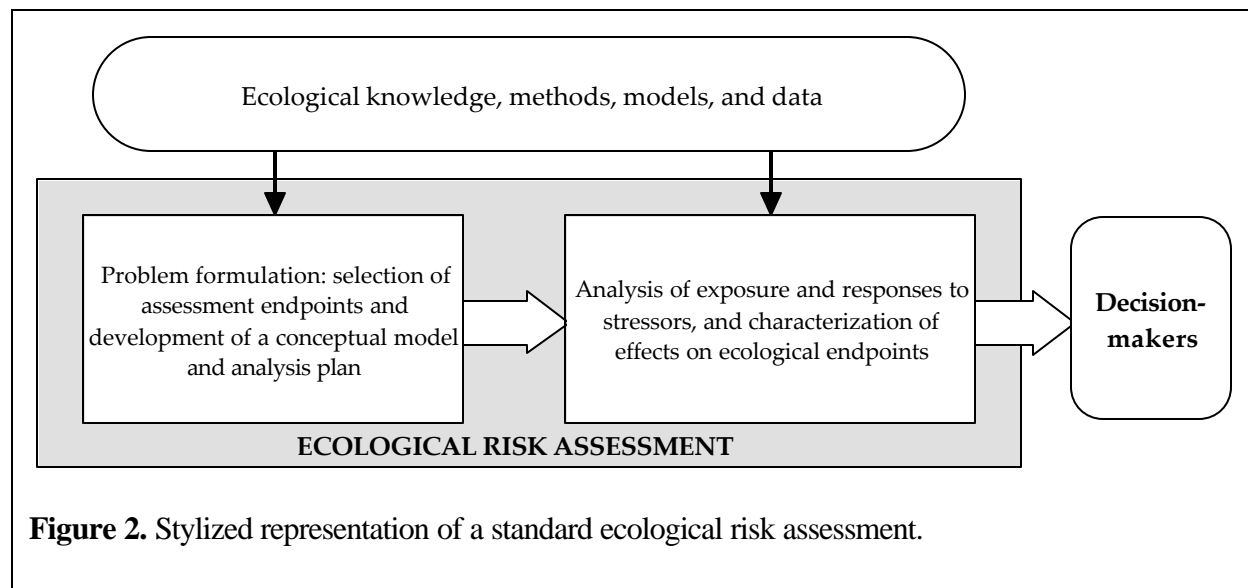


Figure 2. Stylized representation of a standard ecological risk assessment.

If the management goal is to protect against unacceptable adverse effects, a risk assessment may need only to identify a level of exposure below which such adverse effects are not expected to occur. In such cases, a full description of a stressor-response curve is not needed. This is the approach EPA currently uses to establish ambient water quality criteria and cleanup goals for Superfund sites (Stephan et al. 1985, USEPA 1997a). Other management goals (e.g., selection of best management options where some adverse effects cannot be avoided) may require evaluation of changes in ecological endpoints in response to changes in exposure levels for different management options, and thus may need full stressor-response curve information. In these cases, estimated changes in the ecological assessment endpoints can be used to characterize the degree of risk reduction associated with alternative management actions.

Although the assessment process described above appears as a series of steps, the process is generally iterative, with information obtained during initial analyses contributing to refinements or re-evaluations of problem formulation and analysis plans. For detailed information on how the Agency conducts ecological risk assessments, see EPA's *ERA Guidelines* (USEPA 1998a) and *Generic Ecological Assessment Endpoints (GEAEs) for Ecological Risk Assessments* (USEPA 2003e).

The Agency also conducts ecological assessments using monitoring data that represent the condition of various ecosystem attributes (e.g., USEPA 1998b). EPA can use that information to assess the effectiveness of Agency programs in achieving environmental improvements, to identify emerging environmental issues, to document changes in ecosystem condition due to stressors beyond immediate Agency influence (e.g., changes in land use), and to specify the baseline conditions against which the Agency should evaluate the results of its actions. These data also are intended to support prioritization of areas and ecosystems for protection via enforcement actions and voluntary programs (USEPA 1998c).

EPA's primary monitoring efforts include its nation-wide Environmental Monitoring and Assessment Program (EMAP) and several regional EMAP efforts (R-EMAP). EMAP is a long-term research effort designed to assess ecosystem conditions and trends across the United States (USEPA 2002b). In the Aquatic Resource Monitoring component - the only component implemented at the national level to date - EPA uses the physical, chemical, and biological measurements from specified EMAP sampling locations to develop indicators of aquatic ecosystem condition. For more information on EMAP, visit EPA's EMAP website.⁷

3.1.2 Economic Benefits Assessments

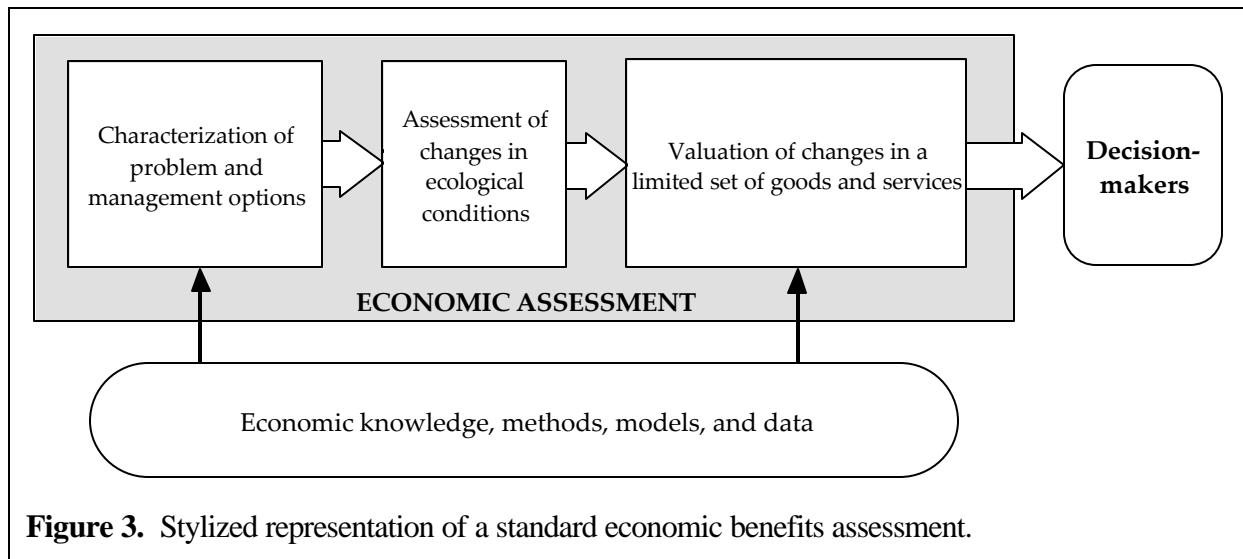
The overall goal of an economic assessment of ecological benefits is to predict the changes in people's well-being that result from changes in ecosystem services. The type of economic analysis that is performed depends on legislative mandates, the type of environmental issues being addressed, and the type of benefits in question. When data or methodological limitations preclude a comprehensive and reliable dollar estimate of ecological benefits, those benefits can be expressed quantitatively (i.e., in biophysical measurements) or even qualitatively. In these situations, an indication of the value of a resource, even absent estimates of change, can provide information to decision-makers about its relative importance.

Figure 3 provides a stylized representation of a standard economic benefits assessment of ecological changes as currently practiced at EPA. In general, the problem is defined by legislative statute or possibly by an ecological risk assessment. Once management options are identified, it usually falls to Agency economists to estimate the benefits and costs of each option. The second stage of the economic benefits assessment is to determine the likely changes in ecological conditions resulting from each potential management action. Often, the only sources of information readily available for predicting ecological changes are the risk assessment, if one was conducted prior to the benefits assessment, or existing studies in the literature.

In the third stage of the economic benefits assessment, changes in ecological conditions are monetized using one or more economic valuation methods. Economists generally attempt to estimate the value of ecological goods and services based on what people are willing to pay (WTP) to increase ecological services or by what people are willing to accept (WTA) in compensation for reductions in them. To enable comparison of policy options, a common unit is needed to express the value of ecological goods and services. The dollar is the preferred unit for valuation, because there is an extensive body of literature addressing its application and interpretation and it is easily compared with costs for considering the net effects of alternative policy choices. Three primary approaches for

⁷<http://www.epa.gov/emap>

estimating these values exist: market-based methods, revealed preference methods, and stated preference methods (USEPA 2000a).



Market-based valuation methods can be used to estimate the gains and losses to producers and consumers where ecosystem changes directly affect commercial activities (e.g., agriculture or commercial fishing). In the simplest cases, increases in commercial production can be valued at the price observed in the market. EPA has used market-based approaches for benefits assessments that include changes in ecosystem goods or services. One example is the *Economic Analysis of the Final Revisions to the NPDES and Effluent Guidelines for [Concentrated Animal Feeding Operations] CAFOs* (USEPA 2003f).

Revealed preference methods can be used to value ecosystem services that, though not bought or sold directly, are associated with goods or services traded in markets. These methods are based on the idea that people's behavior, even outside of well-established markets, reveals the value they place on environmental goods or services. EPA used recreation-demand modeling, a type of revealed preference method, to evaluate actions under the Clean Water Act (CWA); an example can be found in the *Effluent Guidelines, Metal Products and Machinery Final Rule: Economic, Environmental, and Benefits Analysis* (USEPA 2003g).

Unlike revealed preference methods which rely on observed behavior, stated preference methods elicit people's WTP or WTA from surveys that describe hypothetical situations. For example, survey respondents may be asked how much they would be willing to pay to be able to boat, fish, or swim in a lake where water quality problems currently prohibit such activities, but where various efforts at clean-up might achieve conditions that allow or favor those activities. Stated preference approaches are the sole means of estimating non-use values, such as existence value, because they are not associated with any observable functioning market. EPA has used the results of stated preference

research in its economic analyses. For example, EPA relied heavily on a stated preference study of the value of visibility at national parks in its analysis of the 1991 regulation of sulfur emissions at an Arizona coal-fired power plant to improve visibility in the Grand Canyon (see Table 2) (USEPA 1991b). The study was funded by EPA and the National Park Service. A detailed description of the survey and its use in the economic analysis can be found in Morgenstern (1997).

The time and resources available for benefits assessments at EPA, however, are typically insufficient for conducting original economic valuation studies for each new assessment. Thus, benefits assessments often use values estimated for similar ecological goods and services from existing studies, a practice called “benefit transfer.” Most EPA analyses rely on benefit transfer to some extent. Even the Grand Canyon example cited above could be considered an example of benefit transfer. The values applied to visibility improvements at the Grand Canyon in the winter months were initially developed as estimates of improvements in average visibility conditions over all seasons at all national parks in California, the Southwest, and the Southeast.

For more information on how the Agency conducts economic benefits assessments, see EPA’s *Economic Guidelines* (USEPA 2000a). Additional sources of information pertaining to economic benefits assessment can be found in the *Ecological Benefits Assessment Strategic Plan Bibliography*.⁸

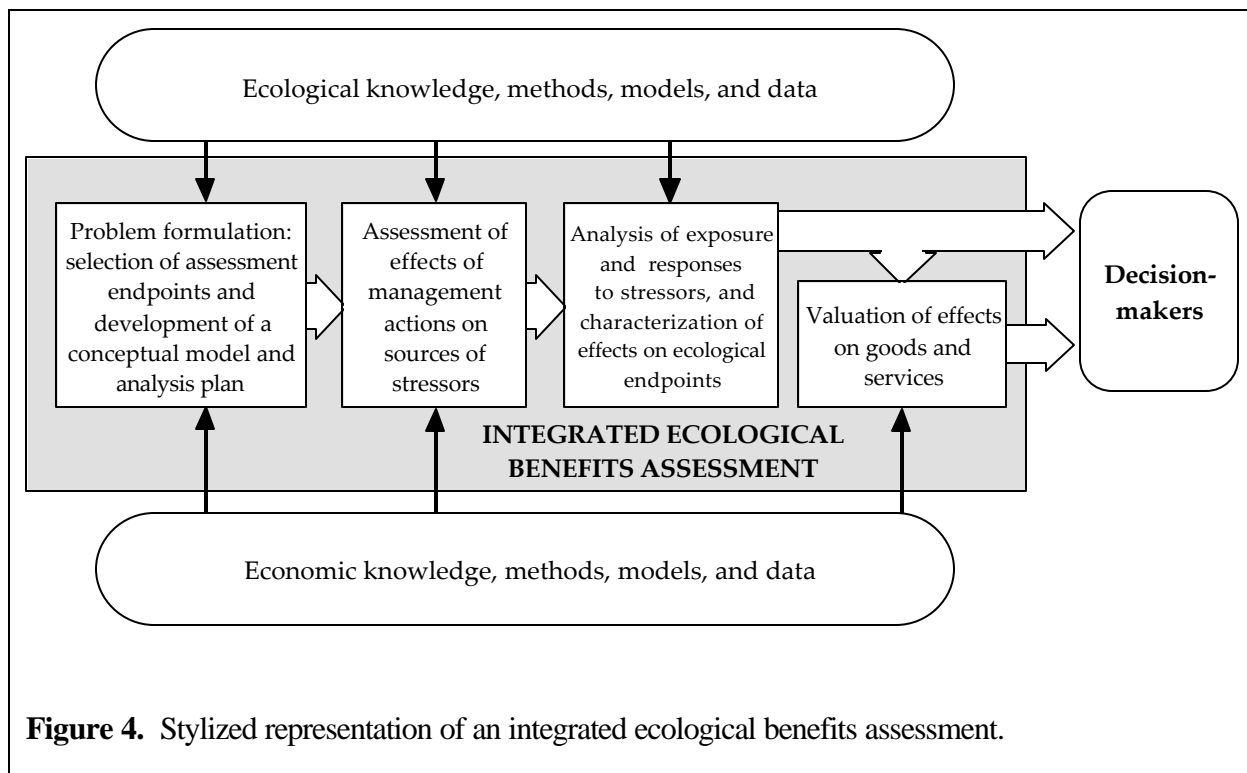
3.2 Towards an Integrated Ecological Benefits Assessment Process

Improving the quality and the coverage of ecological benefits assessments requires a more interdisciplinary approach than is currently practiced. Figure 4 portrays the stages of an integrated ecological benefits assessment, highlighting the contributions of ecology and economics. Arrows from the rounded boxes on the outside illustrate the major stages at which ecological and economic understanding are incorporated in the assessment. As indicated by the arrows, the assessment is a collaborative, interdisciplinary process in which the economic and ecological analysts integrate their understanding, methods, and data in planning and executing the assessment, as indicated in the *Ecological Benefits Framework* (USEPA 2002a).

An integrated ecological benefits assessment is initiated during the planning dialogue among risk managers, stakeholders, economists, risk assessors, and others involved in developing an Agency action or policy. During problem formulation for the integrated benefits assessment, ecologists and economists collaborate to develop a conceptual model of the problem and to identify relevant ecological endpoints upon which the assessment will focus. The conceptual model depicts the results of Agency actions or policy changes on ecological endpoints that reflect the environmental goals of the Agency action and that are most relevant to society. Ecological endpoints that might be adversely

⁸[http:// ...](http://...) [EPA Website to be determined]

affected by the action also are considered. The conceptual model also indicates potential interactions with other ongoing stressors and identifies the temporal and spatial scales at which various relationships will need to be evaluated.



After the problem is characterized and the endpoints are selected, analysts assess the effects of the management action(s) under consideration on the sources of stressors. This stage requires input from ecology and other sciences (e.g., engineering, atmospheric sciences, and hydrology), because it may involve assessing how particular technologies will perform under a variety of natural conditions. This stage also requires input from economists because it may involve assessing how individuals and firms will respond to new information, regulations, or incentives.

The next stage in the benefits assessment process is to assess how the ecological endpoints respond to the changes in stressors brought about by the management actions. This stage may be relatively straightforward when the endpoints are simple indicators of ecological condition, such as pollutant concentrations as a measure of water quality. However, in many cases, the linkages between the stressor and the endpoints will be much more complex (e.g., linkages between exposure to a toxic chemical, individual-level risks of mortality or morbidity, and population-level measures of abundance or viability). The methodological and data requirements at this stage are largely the domain of ecology and other natural sciences, but economists are also involved to ensure that linkages to socially valued endpoints are not overlooked. At the end of this stage, the effects on the ecological assessment endpoints have been quantified, generally in physical terms, or described qualitatively.

1 The final stage in the integrated benefits assessment process is to estimate the value of changes
2 in the ecological endpoints. The methodological and data requirements for estimating trade-offs are
3 largely the domain of environmental economics, but ecologists are involved to ensure consistency and
4 appropriate interpretation of results. By the end of this stage in the process, changes in each ecological
5 endpoint have not only been described qualitatively and quantified in physical terms, but in addition,
6 some measure of their value to society has been estimated.

7
8 As described for the ecological risk assessment process, an integrated ecological benefits
9 assessment can be iterative, with information obtained during initial phases of analysis contributing to
10 refinements of problem formulation and analysis plans for subsequent phases of the assessment. In fact,
11 true interdisciplinary work would mean close collaboration throughout the process such that there is not
12 a rigid delineation of stages. Further, environmental management decisions are rarely definitive, but are
13 constantly being re-assessed to determine their effectiveness and to adapt management strategies to
14 changing conditions. The periodic reporting of surface water conditions and impairments required
15 under Sections 303(d) and 305(b) of the Clean Water Act are examples of this. Therefore, while
16 Figure 4 indicates clear beginning and ending points, in reality the process is continuous.

17
18 At the conclusion of the assessment, the analysts present their estimates of expected ecological
19 benefits associated with each policy option for consideration in the environmental management decision.
20 Clearly, other considerations and analyses may influence the final decisions, but an integrated ecological
21 benefits assessment will provide decision-makers with a more comprehensive understanding of the
22 benefits arising from environmental regulations and management.
23

4 Improving Ecological Benefits Assessments

This section describes some of the major ways in which EPA can improve its capabilities for conducting rigorous and comprehensive ecological benefits assessments on a routine basis. Each subsection describes key issues associated ecological benefits assessments and actions that should lead to improvements in those areas. The actions address institutional changes and directions for future research, data collection, development of analytical tools. The remainder of this section is organized into seven subsections. Section 4.1 describes the information gathering activities used to identify the issues and actions communicated in subsequent sections. Section 4.2 deals with cross-cutting institutional issues, while Sections 4.3 through 4.6 represent the stages in the integrated process depicted in Figure 4; Section 4.7 discusses supplemental valuation approaches.

4.1 Identifying Issues

Development of the *Ecological Benefits Assessment Strategic Plan* (EBASP or the “Plan”) began with an internal evaluation of the current state of the practice of ecological benefits assessment. A staff-level Agency workgroup was assembled to develop the EBASP, and a management-level steering committee was assembled to oversee the effort. Participating offices included the Office of Policy, Economics, and Innovation (OPEI), Office of Research and Development (ORD), Office of Water (OW), Office of Air and Radiation (OAR), Office of Solid Waste and Emergency Response (OSWER), and Office of Prevention, Pesticides and Toxic Substances (OPPTS) (see Text Box 2). The material in this section is based in part upon the understanding of the workgroup and steering committee members regarding ecological benefits assessment and institutional practices at EPA.

The material in this section is based on the insights and expertise of the workgroup and steering committee, which were augmented by information obtained through several information gathering exercises. These include a review of the relevant literature, meetings within EPA and with other Federal agencies, an e-mail survey of EPA risk assessors and managers, and solicitation of input from EPA’s Science Advisory Board (SAB) panel on Valuing the Protection of Ecological Systems and Services. The issues and actions are discussed in general terms. In many cases, additional work is needed to define specific Agency actions, particularly at the program level. Thus, some actions in this Plan prescribe additional information gathering activities.

Section 4.1.1 describes the information gathering activities conducted to identify issues and develop the EBASP, and Section 4.1.2 describes how the workgroup evaluated issues and actions for possible inclusion in the Plan.

Text Box 2. EPA offices participating in EBASP workgroup and steering committee.

Office of Policy, Economics, and Innovation (OPEI) -
National Center for Environmental Economics (NCEE);
Office of Research and Development (ORD) -
National Center for Environmental Assessment (NCEA),
National Center for Environmental Research (NCER),
National Health and Environmental Effects Research
Laboratory (NHEERL),
National Risk Management Research Laboratory (NRMRL),
Office of Science Policy (OSP);
Office of Water (OW) -
Water Policy Staff,
Office of Wetlands, Oceans, and Watersheds (OWOW);
Office of Air and Radiation (OAR) -
Office of Air Quality Planning and Standards (OAQPS);
Office of Solid Waste and Emergency Response (OSWER) -
Office Superfund Remediation and Technology Innovation (OSRTI),
Office of Solid Waste (OSW);
Office of Prevention, Pesticides, and Toxic Substances (OPPTS) -
Office of Pesticide Programs (OPP),

4.1.1 Information Gathering Activities

The workgroup began its task by conducting an extensive and thorough literature review. This review highlighted key technical issues and a need for improved collaboration between ecologists, economists and other analysts involved in EPA benefits assessments.

Between November 2002 and April 2003, workgroup members held a series of thirteen information gathering meetings within EPA and with other Federal agencies. Workgroup members met with economists and ecologists to discuss a wide variety of topics related to ecological benefits assessment. The workgroup learned that many of the information needs specific to ecological risk assessment or general economic issues are addressed in other Agency planning documents. Thus, those information needs are not addressed in the EBASP.

After the information gathering meetings were concluded, the workgroup developed a follow-up e-mail survey to solicit responses to a uniform set of questions about the suspected and known effects of a wide range of environmental stressors on a generic list of ecological endpoints or services. The goals of the survey were (1) to identify the types of ecological stressors that scientists within the Agency believe deserve the most attention, (2) to identify the areas of ecological expertise that are well-represented within the Agency, and (3) to gauge the “state of the science” with respect to predicting

1 major ecological impacts from relevant stressors. Surveys were sent to approximately 400 persons
2 including EPA ecologists that attended the information gathering meetings. A copy of the survey and
3 complete survey results are available from the workgroup.⁹ The results of the survey will be useful for
4 prioritizing research related to ecological risk and benefits assessment.

5 6 7 **4.1.2 Identifying Priority Issues and Actions** 8

9 The information gathering exercises identified a large number of issues and opportunities for
10 improving ecological benefits assessment. The issues presented in Section 4 reflect the workgroup's
11 consensus as to what gaps exist in the Agency's ability to conduct rigorous and comprehensive
12 ecological benefits assessments. The workgroup then evaluated possible actions to improve the
13 Agency's capabilities in those areas. To identify priority actions for inclusion in the EBASP, the
14 workgroup considered several factors, including how well a candidate action addressed the identified
15 ecological benefits issues, whether the action could be carried out in a reasonable amount of time with a
16 reasonable level of effort and resources, whether it promoted collaboration between economists and
17 ecologists, and whether it might assist multiple program offices.

18
19 The EBASP is not intended to prioritize actions for individual program offices. Instead,
20 program offices will each develop their own Action Plans outlining specific research projects that
21 address the needs of their programs. Each Action Plan will indicate how the program office's research
22 projects correspond to the actions described in the EBASP, address the issues in ways not foreseen by
23 the EBASP, or address a previously unidentified need. As described in Section 5, an Agency oversight
24 committee will compile an overall portfolio of projects, including those with both short-term and longer
25 term objectives. The committee will use the portfolio to keep program offices informed of activities
26 planned to meet program-specific and Agency-wide objectives and to promote collaboration among
27 offices and disciplines in those activities when appropriate.

28 29 30 **4.2 Cross-Cutting Issues** 31

32 This section identifies a number of issues and actions that occur across several phases of the
33 ecological benefits assessment process or are institutional in nature. Certain of these address the
34 problems associated with developing an integrated process for assessing benefits of EPA actions
35 (Section 4.2.1), and others deal with internal and external coordination of related assessments and data
36 collection (Section 4.2.2). Still others address handling of uncertainty in ecological benefits assessments
37 (Section 4.2.3).

⁹Contact Steve Newbold (Newbold.Steve@epamail.epa.gov) or Sabrina Ise-Lovell (Ise-Lovell.Sabrina@epamail.epa.gov).

4.2.1 Interdisciplinary Assessment

Assessing the impact of EPA policies on society will involve many disciplines working together. Professionals in engineering, hydrology, and atmospheric sciences may be needed to evaluate the effectiveness of control measures and the fate and transport of contaminants through the environment. Biologists and ecologists are needed to estimate how changes in stressors affect plants and animals and ecological conditions and processes. Economists and other social scientists are needed to assess the value that society places on those effects. Ecological benefits assessment will be improved by Agency-wide efforts to increase understanding and collaboration among its staff in the different disciplines.

Issue: Communication between ecologists and economists within EPA. Every discipline develops its own terminology to facilitate communication, but this often makes communication with those outside the discipline more difficult. Within institutions, even more specific vocabularies may be developed as a means of ensuring consistency across projects. These differences in terminology can lead to misunderstandings between disciplines and institutions that impede collaboration on any given effort. Ecological benefits assessment in particular depends on a high level of mutual understanding between ecologists and economists.

Action: Provide formal and informal opportunities for improving communication among disciplines. By promoting greater interactions between the two disciplines within the Agency, EPA can improve communication between its ecologists and economists. There are many kinds of activities that program offices can undertake to promote greater interactions. Increased formal opportunities, such as organized workshops or symposia within the Agency or seminars within individual program offices, will encourage the exchange of information. Such opportunities also will inform members of other disciplines of methods and results and will improve working relationships across disciplines. Informal opportunities include Division open houses or arranging office space to place disciplines within close proximity. Creation of an interdisciplinary website with references on the basics of both economics and ecology will serve as another informal means of communication. Sponsoring offices will make concerted efforts to consider multiple disciplines and offices when organizing and publicizing such opportunities.

Action: Provide basic training in the fundamentals of other disciplines. For staff who are frequently asked to conduct ecological benefits assessments, or who want to develop the necessary skills, EPA will offer opportunities for cross-discipline training, both at EPA and at other local institutions. The Agency will consider these courses as part of staff development and provide financial and professional support.

Issue: Collaboration between ecologists and economists. Improved communication among disciplines will improve ecological benefits assessments by reducing misunderstandings. True collaboration among ecologists and economists in planning and executing assessments is needed to ensure integrated and comprehensive benefits assessments. Collaboration begins and is especially crucial in the overall planning stage of the action development process and in the problem formulation

stage of a given assessment. Throughout the assessment process, continued collaboration is needed to evaluate interim results and to ensure that needed changes in focus or direction of the assessment are recognized. Collaboration is also necessary in the design and execution of many of the strategic actions identified in this EBASP.

Action: Explore methods for expanding the use of ecological risk assessment information in economic benefits assessments. Although the overall goals of Agency risk assessments differ from those of benefits assessments, there are many overlapping data and methodological needs. EPA will initiate an effort similar to the Risk Assessment for Benefits Analysis (RABA) project, which was initiated in 2000 by the Agency's Risk Assessment Forum to evaluate methods for expanding the use of human health risk assessment information in economic benefits analysis. The interdisciplinary nature of RABA has been key to its success. Similar to RABA, the first step in the new effort will be to conduct one or more case studies to quantify and monetize ecological benefits. The case studies will require collaboration among analysts from different fields and will provide valuable insights into making such interdisciplinary collaboration routine.

Action: Require multi-disciplinary participation in assessing ecological benefits. Neither economists nor ecologists have sufficient knowledge and skill alone to evaluate the benefits of EPA actions in a comprehensive and unified manner. From the outset of an assessment, Agency managers must be sensitive to the need for input from a variety of disciplines and allocate resources, accordingly.

Action: Develop guidelines for planning and conducting ecological benefits assessments. Clear guidelines assist practitioners in meeting the standards of the Agency and assist managers in evaluating the appropriateness and quality of an analysis plan and final assessment. The audience for most formal guidance developed by the Agency includes practitioners within a particular field; there have been few interdisciplinary guidance documents developed by the Agency. An inter-office and interdisciplinary EPA workgroup will develop guidelines for the conduct of integrated ecological benefits assessments. The guidelines will address key issues of planning and problem formulation and implementation of analysis plans. These issues include:

- Construction of conceptual models linking ecological endpoints, ecosystem services, and benefits;
- Identification of appropriate and consistent temporal and spatial scales for analyses; and
- Development of approaches to reducing and describing uncertainty in estimates of ecological changes and the value of those changes.

The guidelines will build upon *A Framework for the Economic Valuation of Ecological Benefits* (or *Ecological Benefits Framework*), issued in 2002 (USEPA 2002a). Steps in developing the guidelines might include development and review of issue papers, conduct of EPA and interagency workshops on specific topics, and development and publication of case study examples.

4.2.2 Internal and External Coordination

The Agency plays a number of overlapping roles in environmental protection, including monitoring human and environmental health, informing the public, assessing risks, and regulating private and public activities. Coordinating the supporting tasks, including research and data collection for benefits assessment, can lead to improved analyses and more efficient use of resources. Research conducted at other federal agencies, universities, and other institutions may also support benefits assessment.

Issue: Coordination of analytical planning. In evaluating a policy or action, the Agency conducts many analyses, including human health and ecological risk assessments and analyses of the costs and benefits of different policy options. In initiating potential actions, Agency policy is to develop an Analytic Blueprint (ABP) to specify the methods and data that will be used to analyze each option. EPA recently issued draft guidelines for the development of ABP's (USEPA 2003h). These guidelines refer to scientific analyses, including ecological risk assessments, as separate from economic analyses, to which benefits assessments are assigned.

Action: Revise EPA's general guidelines for developing Analytic Blueprints. The Agency will revise the ABP guidelines to emphasize the need for coordinated and integrated planning and analyses for estimating benefits of EPA policies, whether ecological or human health benefits. Much of the data used in ecological risk assessments, as well as the risk results, can be useful in benefits analyses, but additional ecological information generally is needed for a comprehensive ecological benefits assessment. Ecologists and economists need to collaborate in identifying the data needed for both assessments during problem formulation. Coordination of data gathering and analyses will greatly improve the cost-effectiveness of these efforts.

Issue: Primary data needed for ecological benefits assessments. Gaps in many types of ecological and economic data impair EPA's ability to assess changes in ecological systems, and the associated monetary values, that may result from its actions and policies. Many data collection and research activities undertaken by the Agency have multiple purposes. For example, toxicological research is used both to evaluate risks of stressors and to estimate benefits of actions that reduce stressors. However, the data used to evaluate risks may not be sufficient to estimate benefits. Further, the relevance of much of the ecological and economic data collected by other federal and state agencies to EPA benefits assessment is generally unknown.

Action: Increase coordination of long-term, large-scale data collection efforts within the Agency. The Agency needs to look beyond short-term programmatic needs toward long-term and large-scale data collection efforts that will assist ecological benefits assessment. Ecologists, economists, and other practitioners of ecological benefits assessment will collaborate in defining such efforts (e.g., identifying needs for environmental monitoring data that describe terrestrial ecosystem condition and

processes, see Section 4.5). Not only can such data sets serve multiple purposes at the Agency, and thus be supported with shared resources, but they also can facilitate national-level analyses, decrease the signal-to-noise ratio in the data, and lead to more accurate and statistically robust estimates of benefits.

Action: Coordinate with other federal agencies to avoid duplication and to leverage available resources to increase the overall quality and quantity of data collected. To obtain data more efficiently, the Agency will collaborate with other agencies where mutual interests allow for combined ecological data collection and consolidated valuation surveys. For example, EPA will use its presence in the interagency and international effort to develop integrated Earth Observation Systems to promote data collection relevant to ecological benefits estimation. This effort presents an ideal opportunity, because it “intends to revolutionize our understanding of the earth and how it works” via data collection that is sustained, comprehensive and integrated.¹⁰

Action: Use research programs to support studies with relevance to ecological benefits assessments. EPA will use its Science To Achieve Results (STAR) grant program and other research mechanisms to inform universities and other external research institutions of Agency needs for ecological, economic, and interdisciplinary research. Funding will provide the necessary incentives to encourage external researchers to engage in policy-relevant studies. Requests for research will emphasize transferability of results across ecoregions, geographic and temporal scales, and landscape contexts.

Action: Address perceived bottlenecks in the data collection process. EPA will coordinate with other federal agencies in discussing with OMB options for expediting approval of information collection requests (ICRs).

4.2.3 Addressing Uncertainty in Ecological Benefits Assessments

Benefits assessments are based on the difference between two forecasts of ecological and economic conditions, one without a policy change or action (the baseline case) and one with a change (the policy case). Generally, both forecasts will be uncertain for a number of reasons, including inherent variability in both ecological and economic processes, measurement error, sampling error, and errors due to model mis-specification. All scientific and economic analyses are subject to one or more of these sources of uncertainty to varying degrees. The Agency and others have made substantial advances in recent years in developing analysis approaches that account for uncertainty in assessing, for example, ecological and human health risks (e.g., USEPA 1997b, 1999). Because it cannot be eliminated completely from benefits assessments, uncertainty should be acknowledged, described, and

¹⁰http://www.epa.gov/geoss/fact_sheets/earthobservation.html.

accounted for to the extent feasible in the interest of making benefits assessments as understandable and transparent to decision-makers as possible.

Issue: Inherent variability in ecological and economic systems. Ecological and economic processes involve some amount of inherent variability. In other words, apparently identical ecological and economic circumstances can produce different outcomes. The portion of the variability in outcomes that cannot be described mechanistically is called “inherent variability” (or inherent randomness or stochasticity). Although its existence is recognized, inherent variability typically is not quantified adequately or is left insufficiently characterized when communicating assessment results. Furthermore, environmental systems generally are not at equilibrium. For example, one ecosystem type (e.g., grassland, lake) can transition to another (forest, wetland) as the result of natural processes. Inherent variability and non-equilibrium dynamics in ecosystems can mask changes in ecological conditions that might be attributable to EPA actions, depending on the magnitude of the effect of the action relative to the inherent variability for each endpoint. Analyzing stochastic and non-equilibrium processes is also important for identifying thresholds and other non-linear behaviors that might significantly alter ecosystem conditions. Improved methods are required for characterizing and communicating the nature of inherent variability and non-equilibrium dynamics in ecological benefits assessments.

Action: Compile data on inherent variability and develop improved methods to account for it in ecological benefits assessments. To assist analysts in conducting ecological benefits assessments on a routine basis, EPA will investigate and compile available data on inherent variability in a number of ecological endpoints that are likely to be used in EPA benefits assessments. The Agency also will support or conduct research to evaluate and refine (as needed) methods for incorporating probabilistic outcomes into benefits calculations, using Monte Carlo techniques, interval mathematics, and other approaches.

Issue: Uncertainty from model mis-specifications in integrated ecological benefits assessments. Until recently, the linkages between ecological and economic systems have been the subject of less intense investigation than issues of “pure” ecology or economics. Until more research is done to identify key ecological endpoints (Section 4.3) and the ecosystem processes that affect them (Section 4.5), there will be a relatively high degree of uncertainty in ecological benefits assessments due to model mis-specifications.

Action: Investigate potential common sources of model uncertainty in ecological benefits assessments. Although every analysis will have its own unique features, some sources of uncertainty due to potential model mis-specifications may be shared by many ecological benefits assessments. Ecological benefits assessments require implicitly or explicitly identifying which ecological processes and conditions directly affect the well-being of individuals or the production practices of firms. The Agency will support or conduct research to identify common sources of model mis-specification and to develop methods to characterize them in ecological benefits assessments.

4.3 Problem Formulation

This section focuses on the first stage of the integrated ecological benefits assessment process depicted in Figure 4: problem formulation. As has already been stressed, interdisciplinary collaboration is crucial in the initial phases of an assessment, including the planning dialogue which precedes problem formulation. Several needs that are relevant to the initial phases of an assessment were already described as cross-cutting needs in Section 4.2. Those include improved interdisciplinary communication and training, ecological benefits assessment guidelines, revised ABP guidelines to emphasize interdisciplinary planning in policy action development, enhanced organizational coordination, and research to improve characterization of uncertainty in benefits assessments. Issues specific to problem formulation include the need to establish workable approaches for early collaboration in developing conceptual models and analysis plans and the need to identify assessment endpoints appropriate for use in ecological benefits assessment.

Issue: Interdisciplinary participation in problem formulation. The collaboration between ecologists and economists that began during the planning dialogue needs to expand during problem formulation to encompass the analysts who will conduct the assessment and other analytic consultants. A number of important issues must be addressed, including the selection of assessment endpoints, the linking of potential ecological changes to changes in the flow of ecosystem goods and services, and the development of the analysis plan that will guide the rest of the assessment.

Action: Organize a series of program-specific problem formulation workshops. ORD will collaborate with program offices to organize these workshops. By working through conceptual models for several example ecological benefits assessments specific to a given program area, participants will gain experience in formulating problems that require multiple disciplines to fully appreciate. The workshops will not only make exchanges across disciplines routine, but they will help participants both to resolve issues that can impede collaboration and to develop effective working relationships in advance of planning and problem formulation during actual programmatic assessments. Program-specific workshops offer the added advantage of allowing participants to focus on program-relevant management actions or upcoming action development analyses for their office.

Issue: Identifying clear linkages between ecological endpoints, ecosystem goods and services, and benefits categories. Many ecologists and economists have little experience identifying and describing conceptual linkages between sources of environmental stress and ecological functions and conditions on the one hand, and ecological goods and services and categories of benefits on the other.

Action: Develop a set of generic ecological benefits assessment endpoints. An interdisciplinary and interoffice Agency workgroup will develop and publish a reference document for benefits assessors identifying some common ecological goods and services that might be affected by EPA actions. The reference will be similar to EPA's recently published *Generic Ecological*

Assessment Endpoints (GEAEs) for Ecological Risk Assessment (USEPA 2003e). Generic ecological benefits assessment endpoints will help analysts during problem formulation by providing them with some standardized “building blocks” that could be tailored to their specific situation. The endpoints will be general enough to be relevant for a variety of policies or actions, but specific enough to be clearly distinguishable from each other and suggestive of operational measures that could be used in particular situations. The actual endpoints used in a particular assessment would be determined by the details of the situation.

4.4 Evaluating the Effectiveness of Management Options

The second stage of an integrated ecological benefits assessment, as portrayed in Figure 4, is to estimate the immediate impact of a policy or management action on the main sources of environmental stress that are the target of the action. For example, if a pesticide is the stressor of concern and EPA establishes a rule restricting its use, how will the restriction affect patterns of use of other pesticides by farmers? If an environmental education program is established to reduce storm water impacts, will municipalities, firms, and citizens change their behavior, and if so in what ways? If contaminated sediments in a harbor are capped, will the contaminants remain effectively covered? If agricultural drainage tiles are interrupted to restore a wetland, will wetland vegetation return, and if so when? This section focuses specifically on two main areas where additional information is needed to assess the immediate impacts of policies or actions on targeted environmental stressors: human behavioral responses (Section 4.4.1) and the effectiveness of pollution control, remediation, or restoration measures (Section 4.4.2).

4.4.1 Behavioral Responses to Management Actions

Behavioral responses by individuals or firms that are directly or indirectly affected by an environmental policy or management action can have a large influence on the overall effectiveness of the action. Thus, in a benefits assessment, it is important to accurately predict behavioral responses, both for mandatory regulations and for voluntary programs. For example, a benefits assessment for a proposal to ban a particular pesticide should estimate whether farmers are likely to substitute another pesticide for the banned one, which may lead to unanticipated adverse ecological impacts. A proposal for either a voluntary program or economic incentives for the installation of settling ponds designed to prevent animal manure from reaching surface waters should determine how many farmers would participate and whether the settling ponds would transfer some or all of the pollution from surface water to ground water.

Issue: Knowledge of behavioral responses to different types of regulatory strategies.
More information is needed on how targeted groups react to environmental policies, including traditional command-and-control regulations, policies based on economic incentives, and voluntary

1 programs. For example, EPA might propose a tax on runoff volume, rather than a specific control
2 technology, to reduce urban storm-water runoff. The response of a firm to the tax may be runoff
3 mitigation, relocation to untaxed areas, or payment of the tax with no efforts at runoff reduction. In
4 order to accurately estimate the benefits of a tax versus mandated controls, EPA needs to predict these
5 behavioral responses. In cases where EPA simply provides information on best practices or develops
6 voluntary programs, the number of individuals or firms expected to adopt the practice or participate in
7 the program must be estimated to accurately predict the benefits of the action. Many previous
8 voluntary and informational programs related to agricultural practices primarily were intended to
9 improve farm productivity. More recent programs, such as the Conservation Reserve Program, the
10 Wetlands Reserve Program, and wetlands mitigation banking programs, focus more on ecological
11 protection and promote ecologically based management practices with economic incentives to
12 encourage participation. To date, relatively little research has been conducted on behavioral responses
13 to opportunities for participating in voluntary ecological protection programs. It is likely that the factors
14 influencing participation in these newer programs are different from those of the previously studied
15 programs.

16
17 *Action: Support research on behavioral responses to environmental policies.* EPA will
18 support research that compares the effectiveness of traditional command-and-control regulations with
19 those based on economic incentives. The Agency will emphasize levels of reduction in the
20 environmental stressor and changes in ecological conditions. EPA also will support studies on the
21 differences in costs to the targeted groups from mandated controls versus economic incentive
22 programs. Decisions to adopt voluntary ecological protection measures could be influenced by a
23 number of factors. For example, farmers' participation decisions could be influenced by the type of
24 crop grown or livestock raised, the environmental attitudes and knowledge of the farmer, the size of the
25 farm, the farm financial situation, and other characteristics of the farm, the farmer, and the measure.
26 Once the most important factors are identified, data on those key factors will be collected for relevant
27 sub-groups of the population. EPA will support further research on the magnitude of the influence of
28 each factor and will support the application of research findings in this area to benefits assessments of
29 new policy cases as they arise.

30 31 32 **4.4.2 Effectiveness of Pollution Control, Remediation, or Restoration Measures**

33
34 If a given technological or ecological protection measure is employed as part of the
35 implementation of an EPA policy or action, ecological benefits will be realized only to the extent that the
36 measure is effective in reducing stressors or rehabilitating damaged ecological structure or function.
37 EPA has a long history of research on the effectiveness of technological measures for pollution control.
38 At present, ORD's Environmental Technology Verification (ETV) Program conducts much of the
39 Agency's technological effectiveness research.¹¹ ETV performs verification of voluntarily submitted

¹¹ <http://www.epa.gov/etv/>

commercial products or technologies in areas including air pollution control, source water protection, storm water control, greenhouse gas reduction, pollution prevention, and waste reduction. However, ETV only examines commercial products or technologies. EPA policies also direct how toxic substances can be used or must be handled. Further, an increasing number of the Agency's actions make use of ecological protection measures (i.e., the design and use of "ecological engineering" methods, such as ecological restoration). These approaches can result in lower long-term costs and many ancillary ecological benefits such as the provision of wildlife habitat and increased property values. For example, surface water impairments due to sediments, altered flow regimes, and disturbed habitat are often addressed through methods that help simulate original watershed conditions, such as best management practices (BMPs) and ecologically enhanced riparian corridors, stream channels, or wetlands.

Issue: Measuring effectiveness and estimating ecological outcomes of ecologically-based pollution controls or restoration practices. Ecologically-based pollution controls are predicated on the fact that the environment, or different environments, can absorb some level of stressors without unreasonable adverse effects. For example, some pesticides may be particularly harmful to aquatic organisms, but not to terrestrial vegetation. In such a situation, the Agency may require the use of a vegetated buffer strip near waterways. However, the functional effectiveness of various kinds of ecological pollution controls and restoration practices has not been well studied. Where ecologically-based approaches have been studied, effectiveness is sometimes defined too narrowly to support the estimation of ecological benefits. For example, much of the research on the design of BMPs or watershed restoration approaches has focused on unit performance parameters, such as the establishment of design criteria to meet a sediment removal objective at lowest financial cost. System-level design parameters required to achieve ecological outcomes, such as numerical improvements in biological criteria, are still unknown, and EPA has not yet achieved the disciplinary integration needed to determine them.

Action: Support research to measure the effect of ecologically-based pollution controls on the fate of stressors in target environments. Reduction in emissions or changes in the media through which stressors must pass should lead to reductions in pollutant concentrations in sensitive environments. Estimating that reduction, which is necessary to predict the extent of changes in the ecological assessment endpoint, requires the use of atmospheric, hydrological, and other fate and transport models. While some of these models are quite well developed, others require development, refinement, or parameterization for specific situations, regions, and scales. EPA will support research that parameterizes the effectiveness of ecologically based pollution controls on reducing pollutant concentrations in target environments. EPA will emphasize applications of the research in predictive model development and refinement.

Action: Support research examining the influence of key ecological restoration design parameters on the provision of ecological services at various scales. Examples of ecological restoration design parameters include the location of a restoration project in a watershed (e.g., in the headwaters or further downstream), width of vegetation buffers, and shape of habitat patches. ORD is

1 broadening its current studies on improving land-based and in-stream ecological restoration measures
2 to include indicators of in-stream ecological conditions. For example, ORD is examining the effects of
3 stream restoration on nitrogen processing for an urban, coupled stream-aquifer, and is relating sediment
4 removal rates of BMPs, such as buffer strips, to actual improvements in stream water quality. EPA will
5 support additional research in this area, emphasizing broader geographic scales to assist in large-scale
6 ecological benefits assessments.

7
8 *Issue: Monitoring the performance of ecological restoration projects and pollution*
9 *controls.* Traditional prescriptions for evaluating restoration effectiveness, such as long-term, intensive
10 monitoring of experimentally treated and untreated watersheds, have so far met with limited success.
11 When spatial variability, year-to-year climatic variability, and other confounding factors are considered,
12 the cost and duration required for obtaining appropriate control data for comparison with treated
13 watersheds are sometimes prohibitive. Therefore, few such evaluation studies have achieved conclusive
14 results. Furthermore, information on the locations and characteristics of the large number of funded
15 restoration projects is not well organized. Monitoring of stressor levels in sensitive environments is
16 frequently short-term and limited in scope.

17
18 *Action: Develop and use both intensive and extensive monitoring designs to track the*
19 *performance of ecological restoration projects.* EPA will improve effectiveness determinations for
20 individual projects (i.e., intensive monitoring) by strengthening monitoring requirements as a condition of
21 project funding. The Agency will pursue extensive efforts through ORD's Environmental Monitoring
22 and Assessment Program (EMAP), including its regional component, R-EMAP. EMAP is one of
23 EPA's primary monitoring efforts and already has developed much of the science needed to underpin a
24 state-based statistical monitoring framework to determine condition and trends for all of the Nation's
25 aquatic ecosystems. A companion effort is needed to provide representative data on the location,
26 condition, and extent of ecological restoration measures in watersheds of interest. EPA will first study a
27 large number of watersheds and categorize them by the amount and kind of restoration already
28 completed. Next, the various categories will be monitored, using efficient sampling designs to ensure
29 sufficient watershed numbers for determining the changes in indicators of ecological health as a function
30 of restoration type. New monitoring approaches to synthesize information from a large number of
31 environments need to be developed, tested, and transferred to local entities responsible for
32 environmental management. New or refined methods will also be developed or sought that combine
33 data from different pollution monitoring efforts, which may occur over limited time and space, in order
34 to measure the effectiveness of ecologically-mediated controls and improve fate and transport models
35
36

37 **4.5 Analyzing Ecological Changes**

38
39 The third stage of an integrated ecological benefits assessment, as depicted in Figure 4,
40 involves analyzing the ecological changes expected to result from an EPA management action by
41 forecasting ecological conditions for the baseline (no action) case and for the policy (action) case.

There are three key areas associated with this stage for which additional investment could significantly improve the Agency's abilities to assess ecological benefits: characterizing baseline ecological conditions for comparison with projected changes (Section 4.5.1), predicting changes in populations over time (Section 4.5.2), and predicting changes in ecological processes over time (Section 4.5.3).

4.5.1 Establishing Baselines for Ecological Condition

An ecological benefits assessment requires estimating the degree of change in the flow of ecosystem goods and services that might result from an Agency action compared with the "no-action" alternative. For benefits assessment, this baseline condition must be projected into the future so that the stream of benefits can be estimated over time.

To forecast baseline and post-action conditions, analysts need to consider natural variability (Section 4.2.3) and underlying directional trends in background conditions. Directional trends in conditions can result from ongoing natural changes or anthropogenic stressors, including stressors that are not targeted directly by an Agency action but that can nevertheless influence the response of ecosystems to the action. For example, the effectiveness of an EPA action to restrict the amount of pesticide applied on a per-acre basis to certain crops will depend on whether and how much the total acreage of those crops changes in the future, either as a result of the action itself or as a result of unrelated changes in the agriculture sector. If such background changes can be anticipated, they should be incorporated into a benefits assessment. The existence of other Agency programs that diminish certain stressors also contribute to changing baseline conditions over time.

There are many ongoing environmental monitoring efforts by federal, state, and other agencies. As noted in Sections 3 and 4.4.2, EPA established EMAP to assess status and trends in ecosystem condition across the United States. Initiated in the 1980s, EMAP has established measures, indicators, and monitoring designs and locations for some, but not all, aquatic ecosystems. Aquatic ecosystems currently covered by EMAP include wadable streams, estuaries, near coastal waters, the Great Lakes, large rivers in the central basin, and, through R-EMAP, lakes and reservoirs. Measures and monitoring designs for wetlands and offshore waters currently are under development. EMAP does not cover terrestrial ecosystems. EPA ORD's Western Ecology Division is developing a Program to Assist in Tracking Critical Habitat (PATCH). PATCH is a spatially explicit, terrestrial ecosystem simulator with minimal data requirements.¹² The monitoring efforts of several US Department of Interior (DOI) services recently have been consolidated under the US Geologic Survey (USGS) (e.g., Geographic Analysis and Monitoring Program, National Biological Survey, National Breeding Bird Survey). The Committee on Environment and Natural Resources of the National Science and Technology Council recommended a framework for integrating environmental monitoring efforts across the Nation and linking those efforts to predictive modeling and ecological process research (CENR 1997). The Heinz

¹²www.epa.gov/wed/pages/models/patch/patchmain.htm

Center for Science and Economics and the Environment report, *State of the Nation's Ecosystems* (Heinz Center 2002) and EPA's 2003 *Draft Report on the Environment* (USEPA 2003i), lists these and other monitoring efforts conducted by federal, state, and other agencies. The Millennium Ecosystem Assessment (MA) is an international program initiated by the United Nations in 2001 to provide decision-makers and the public with needed scientific information on the consequences of ecosystem change for human well-being and options for responding to those changes. The initial MA, which addresses conditions and trends in ecosystem services including food, timber, fuel, fibre, nutrient cycling, waste processing and detoxification, regulation of natural hazards, and cultural and amenity services, is currently under review.¹³

Issue: Monitoring program design and ecological benefits assessment. None of the environmental monitoring programs developed to date have been designed with ecological benefits assessment in mind. In its 2000 report *Ecological Indicators for the Nation* (NRC 2000), the National Academy of Sciences (NAS) recommended a series of ecological indicators to assess changes in ecological processes and products that potentially could provide a foundation for ecological benefits assessments in the future. The report was issued in response to an EPA request for assistance in its research program on ecological indicators. It recommends a series of ecological measures that can be aggregated into nationwide indicators of ecosystem extent, condition, functioning, and ecological capital. Those indicators relate to land cover, total species diversity, nutrient runoff, carbon storage, lake trophic status, nutrient balance, and soil organic matter. Some of the recommended indicators are based on measures from existing monitoring programs, whereas others will require new monitoring programs. Implementation of the full suite of indicators would be best achieved by leveraging the monitoring capabilities and resources of several federal agencies.

Action: Evaluate the NAS recommendations for implementing ecological indicators. EPA will establish a workgroup of analysts familiar with benefits assessment practices and data requirements to evaluate the NAS report recommendations. The workgroup might sponsor one or more interagency meetings or workshops as part of its activities to evaluate the report. The workgroup will establish criteria to evaluate several characteristics of the proposed indicators including coverage of ecosystem goods and services (e.g., see Table 1), the strength of the relationship between the indicators and specific ecosystem goods and services, adequacy of sampling design to facilitate national benefits assessments, relevance of existing monitoring data for the indicators, research needed to fully develop indicators, and different agency responsibilities and partnerships in developing specific indicators. The evaluation report will recommend a suite of indicators and a long-term interagency plan for their implementation.

Issue: Unknown relevance of current ecological monitoring programs to ecological benefits assessments. In the short term, analysts need to make the best use of available data. Even though past and ongoing environmental monitoring programs were not established with ecological

¹³ www.millenniumassessment.org/en/products.chapters.aspx

benefits assessment in mind, some existing ecological data acquired to date may be useful in this context. The extent to which existing data can be applied to ecological benefits assessments is unknown, although the NAS report mentioned above provides some information.

Action: Assess the relevance of existing monitoring programs to ecological benefits assessments. Documents such as the NAS (NRC 2000) and Heinz Center (2000) reports and the EPA (2003i) *Draft Report on the Environment* identify a wide variety of existing monitoring programs, measures, and indices of ecosystem condition. Some of those monitoring programs will already have been reviewed by the workgroup under the previous action. A similar workgroup will evaluate those and other monitoring programs to identify their utility for ecological benefits assessment at the Agency. For each, EPA will evaluate:

- The relationships of measures and multi-metric indices (i.e., indices that combine different metrics into a single index value) monitored and reported by the program to ecosystem goods and services;
- The statistical power of the program's sampling design and duration of sampling to detect trends despite natural variation in environmental conditions and stressors; and
- The sensitivity of changes in measures or indices to EPA actions.

EPA will publish its findings in a resource document that describes the relevant ecological monitoring programs, identifies the correspondence between specific measures and indices and ecosystem goods and services, and provides recommendations for focusing future studies or monitoring efforts to assist benefits assessment. Interagency collaboration will be needed to cover both aquatic and terrestrial monitoring programs.

Action: Recommend refinements of existing ecological monitoring programs and multi-metric indices. As they conduct the actions noted above, EPA workgroups will look for opportunities to refine existing monitoring programs to collect data that are more useful for ecological benefits assessments. Refinements might be related to sampling design, measures used, and method of aggregating measures into indices. Given the potentially large number of ecological effects that might stem from a single action, some representing improvements and others deterioration, expanded use of multi-metric indices that condense information on ecosystem condition to reflect net improvements (or losses) could simplify analytic resource requirements for ecological benefits assessments. Although multi-metric indices are widely used in surface water quality monitoring (e.g., index of biotic integrity, or IBI) and wildlife protection programs (e.g., habitat suitability indices), ecological benefits assessments may require the development of different indices or different measures altogether. In addition to the development of new multi-metric indices, such approaches may also consist of integrating ecological benefits measures into existing indices. Where possible, the workgroups will make recommendations for such refinements in existing programs.

1 *Issue: Short duration and localized coverage of many monitoring programs.* Because of
2 the natural variability inherent in ecosystems over time and space, characterizing baseline conditions and
3 predicting changes in ecosystem conditions require appropriate measurements over large geographic
4 areas over long periods of time. While some monitoring efforts have been ongoing for decades, most
5 have been relatively brief, reflecting the challenges of obtaining funding to sustain monitoring programs
6 over time. Certain types of data are collected at the state level, with varying levels of consistency from
7 state to state (e.g., water quality measures). The actions taken under the previous issue should identify
8 several monitoring programs that have collected data relevant to ecological benefits assessment, but for
9 which the data cover shorter periods of time or smaller geographic areas than is needed for national-
10 level benefits assessments.

11
12 *Action: Develop methods for using measures from short-duration and localized*
13 *monitoring programs in ecological benefits assessments of long-term, large-scale actions.* EPA
14 will evaluate approaches to projecting ecological changes over time using data from short-term
15 monitoring efforts. The approaches will address the uncertainties associated with unknown ranges of
16 natural variation and the influence of extreme events on ecosystem response (see Section 4.2.3). EPA
17 also will investigate methods for aggregating specific relevant ecosystem measures that are collected at
18 state and regional levels to develop unbiased national projections. Of particular concern here are the
19 inconsistencies between data collection methods across monitoring programs and differences in
20 ecosystem responses to changing stressors across ecoregions. This effort might be conducted by EPA
21 alone or in concert with staff from other federal and state agencies.

22
23 *Action: Encourage more investment in long-term, large-scale monitoring programs.* To
24 be most effective, this action should be a collaborative effort among federal agencies responsible for
25 monitoring various aspects of both aquatic and terrestrial ecosystems (e.g., EPA for water, USGS and
26 US Forest Service (USFS) for terrestrial ecosystems). An interagency working group familiar with the
27 previous actions can recommend which ongoing monitoring programs most merit continued investment
28 and enhancement for purposes of benefits assessment. Evaluation criteria would include utility of
29 measures for multiple agencies and for multiple purposes. An outcome might be a recommendation that
30 EPA partner with other agencies to develop a program parallel to EMAP for terrestrial ecosystems. A
31 starting point would be meeting with CENR to discuss its proposed framework for integrating
32 environmental monitoring efforts across the nation.

33
34 *Issue: Ability to account for multiple stressors.* The existence of multiple, ongoing stressors
35 poses challenges to forecasting ecological conditions under both baseline and policy action scenarios.
36 Many of those stressors are presently outside the focus of much of EPA's ecological research in
37 support of its traditional regulatory mandates (e.g., determining water quality standards, pesticide
38 application requirements, cleanup levels for contaminated soils or sediments). Three such
39 "unconventional" stressors are widespread and are likely to continue to increase in magnitude over the
40 foreseeable future: global climate change, land-use alterations, and introductions of non-native species.
41 Although these are active areas of research, more information is needed to reduce uncertainties
42 associated with assessing their effects in a multi-stressor context. Much remains unknown about these

stressors, including their prevalence, factors that influence them, their effects on the flow of ecosystem goods and services, their relationships to other stressors, and their responses to actions to address them intentionally or incidentally. Additional understanding of the importance of landscape context, areal extent, ecological history, and hierarchical relationships in relation to these stressors also is needed. For example, the influence of areal extent on ecosystem services is likely to be non-linear in many cases (e.g., as habitat is lost, eventually there is a quantity and spatial distribution of the remaining habitat that will not sustain a viable population of a given species).

Action: Develop case studies that characterize effects of “background” stressors on ecosystem responses to stressors targeted by Agency actions. The Agency will sponsor one or more workshops or other fora in which Agency ecologists will attempt to project baseline ecological conditions into the future for a set of case studies. The exercise will include evaluation of the potential for progressive changes in stressors that EPA has few options to manage (e.g., land use change, introduced pest species) to influence ecosystem responses to stressors that are the target of an Agency action. For each case, participants will evaluate different conceptual models for predicting changes in populations or ecosystem condition from different patterns of change in multiple stressors over time. This exercise should help to identify where additional information is most needed to predict responses of populations and ecosystems to changes in an Agency-targeted stressor against a background of other stressors that may be changing over time.

4.5.2 Assessing Changes in Ecological Populations

Species populations confer many types of benefits, including marketable commodities (e.g., harvested species), direct-use (e.g., recreational hunting and fishing), indirect-use (e.g., maintaining biodiversity, pollination, seed dispersal), and non-use (e.g., existence value). Thus, ecological benefits assessments often must value changes in specific plant or animal populations.

Population-level endpoints important for benefits assessments include standing biomass, harvestable biomass, spatial distribution, population size, individual age and size distribution, and population density. Many existing models used to predict changes in population endpoints associated with exposure to chemical stressors are based on a “bottom-up” approach that uses exposure-response data on individual-level effects (e.g., reproduction, growth, and survivorship) to predict changes in population size and age structure. Exposure-response data on behavioral endpoints, such as ability to escape from predators or ability to find prey, in principle can be factored into estimates of survivorship. To be most useful for benefits assessments, these models should incorporate data from full exposure-response functions so that incremental changes in parameters such as reproductive success can be simulated.

Another population-level endpoint of concern is the probability of extinction, either of local populations or of entire species, which would affect species diversity and possibly ecosystem functions. For assessments where population extinction is a possibility under a no-action or action alternative,

landscape characteristics may need to be incorporated into spatially explicit models. For example, habitat patch size affects the likelihood of local extinction, and patch connectivity influences opportunities for re-establishing local populations through immigration.

Models that simulate population responses to chemical stressors generally require not only individual-level exposure-response data on several sub-lethal endpoints, but also data on the species' life-history. In addition, many aspects of a population's interactions with other species in its environment are density-dependent. For many species, the numeric value of certain life-history parameters (e.g., reproductive success) changes with the density of the population, given a fixed "carrying capacity" of the environment with respect to food and other resources needed by the population. For example, at moderate to high population densities of many animal species in a given environment, as population density increases, emigration increases, or if that is not possible, reproductive success or juvenile survivorship decrease. Alternatively, at low population densities, population size can decline further owing to difficulties in finding mates, inbreeding, or other mechanisms. Thus, some population simulation models can be complex and specific to a given species life history and habitat configuration.

Issue: Ability to predict population-level responses to changes in environmental stressors. The population models in use for ecological benefits assessment at EPA represent a subset of the models published in the open literature and in use by other federal and state agencies and institutions. Although ORD is conducting extensive research into population modeling (e.g., USEPA 2004), benefits analysts may be unaware of different modeling approaches or may not have access to the full range of population models available. In addition, guidance on selecting among model options to support benefits assessments is lacking.

Action: Create a catalogue of existing population models and develop guidance for model selection and use. To assist Agency analysts attempting to value changes in species populations in benefits assessments, EPA will conduct a survey of existing population models in use at EPA and other federal agencies and develop a catalogue of those models. The catalogue will describe each model's range of applicability, input requirements, and output characteristics. This action will help identify opportunities for adapting existing population models to ecological benefits assessment and identifying needs for new population modeling capabilities across program offices.

Action: Expand integration of population and economic models for use in benefits assessment. Where economic benefits of one or more programs are substantively linked to changes in populations of certain species or groups of species, EPA will pursue options for integrating population models with appropriate economic models. Integration of population and economic models allows for precise matching of population model outputs with needed economic model inputs and for modeling feedback between changes in population endpoints and socio-economic responses.

Issue: Data to predict population-level responses from individual-level effects. The Agency has data for evaluating the acute lethality of thousands of chemical stressors on many different

types of species (e.g., fish, invertebrates, algae, rodents). The Agency also has information on exposure levels associated with no-observed-adverse-effect levels (NOAELs) and lowest-observed-adverse effect levels (LOAELs) for many chemicals and typical laboratory species. Those data have been adequate for informing most Agency ecological risk management decisions for toxic chemicals. Thus, full exposure-response data on sub-lethal effects related to reproduction, life-span, and growth rate have either not obtained, reported, or compiled for most chemicals, yet are necessary for many population simulation models.

Action: Develop estimates of full stressor-response relationships on sub-lethal endpoints for more stressors. Although EPA has obtained a substantial quantity of full exposure-response data for mortality and some sub-lethal endpoints for pesticides and other toxic chemicals, those data need to be compiled in readily accessible formats. EPA program offices also need to encourage reporting of full exposure-response functions for sub-lethal effects when such data are collected, even where current reporting requirements might only specify 50 percent mortality levels and NOAEL/LOAEL values. As discussed in Section 4.2.1, EPA's Risk Assessment Forum is sponsoring the Risk Assessment for Benefits Analysis (RABA) project. RABA was designed to improve the estimation of human health benefits by finding ways to better characterize the expected incidence of adverse effects in a human population at different levels of exposure.¹⁴ The Agency will conduct a similar project to investigate approaches to better characterize the expected incidence and severity of individual- and population-level effects in ecological risk assessments.

4.5.3 Assessing Ecosystem Processes

While some ecological benefits can be directly linked to ecosystem components such as particular species that support outdoor recreation, others are better associated with ecosystem functions/processes. Thus, benefit assessments also require attention to ecosystem processes that support services beneficial to people. Examples of such services include pollination, seed dispersal, nutrient cycling, water recharge, flood protection, climate control, and primary productivity (see Table 1 for additional examples of ecosystem services).

Changes in ecosystem processes can be direct or incidental consequences of EPA actions. An example of incidental consequences of an EPA action is improved flood water retention and maintenance of cold-water fisheries resulting from an EPA action to reduce sedimentation in a watershed to meet water quality turbidity criteria.

Issue: Ability to predict changes in ecosystem processes in response to changing environmental stressors. Although many types of community- and ecosystem-process simulation models exist, few address processes that support the indirect-use services listed in Table 1 and noted

¹⁴<http://cfpub.epa.gov/ncea/cfm/recorddisplay.cfm?deid=56433>

above. Using the sedimentation example, EPA is unaware of any hydrodynamic model that relates reduced sedimentation to changes in flooding frequency or magnitude at a watershed or other geographic scale. Many ecosystem process models that other agencies and research institutions have developed are primarily research tools and specific to the ecosystem type and geographic scale for which they were developed. To be useful in benefits assessment, such models need to be adapted to or developed for a range of ecosystem types, large geographic scales, and multiple concurrent stressors.

Action: Identify which ecosystem processes are most important to benefits assessments at EPA. A first step in improving EPA's ability to predict changes in ecosystem services is simply to identify which ecosystem services, and the ecosystem processes that support them, are likely to be most affected, directly and indirectly, by EPA actions. An interoffice working group of economists and ecologists will prioritize the direct- and indirect-use ecosystem services listed in Table 1 and in other relevant publications with respect to relevance to EPA programs and mandates for action. The group then will identify and define the ecosystem processes that equate to or support those services. Finally, the group will identify the ecosystem processes for which EPA has the greatest modeling needs.

Action: Identify which of the important ecosystem processes need further research to allow model development. Current understanding of the relationships between landscape characteristics, geographic scale, ecosystem type, and other factors and ecosystem processes related to services such as pollination, seed dispersal, flood control, micro-climate control, nutrient cycling, and others, is limited. An interdisciplinary working group including program office and ORD scientists will evaluate current understanding of the ecosystem processes identified as high priority in the previous Action. For those important ecosystem processes for which current understanding is inadequate to allow predictive modeling, the group will recommend both near-term and longer term research priorities for both internal and extramural ORD support to improve understanding and model development.

Action: Develop catalogue of existing relevant ecosystem process models at different geographic scales to support benefits assessment. As indicated earlier, EPA is not the only federal agency evaluating both the benefits and costs of its actions. In collaboration with the US Army Corps of Engineers and other federal agencies, EPA will establish a working group to develop a catalogue of existing ecosystem process models that are relevant for assessing ecosystem services of value to humans. The working group will evaluate those models for their potential to transfer across geographic scales and ecosystem types. The group also will identify opportunities for linking existing ecological models, needs for new ecosystem process models, and opportunities for integrating ecosystem and economic models to enhance ecological benefits assessment.

Action: Expand portfolio of models to address the ecosystem processes important to benefits assessment at multiple geographic scales. As additional research provides improved understanding of the relationships between changes in ecosystem stressors, processes, and important services, EPA will develop additional ecosystem models to facilitate benefits assessment. As those models are developed, EPA will expand its documented portfolio of ecosystem models for benefits

assessment. The portfolio will address multiple geographic scales for assessment and emphasize opportunities for transfer of models among ecosystem types.

Action: Address data needs for those models. Concurrent with the development of new models to predict changes in ecosystem processes and services in response to EPA actions, EPA will specify the data needed as input to such models. An Agency working group will evaluate those data needs against existing and proposed Agency data collection activities for ecological monitoring, risk, and benefits assessments. The group will provide recommendations for refining or augmenting those activities.

Action: Evaluate other options for estimating changes in ecosystem processes. Mechanistic process modeling is not the only approach for predicting large-scale changes in ecological conditions and processes in response to EPA actions. A survey of literature and data relating stressors or indices of ecosystem condition to ecosystem processes/services will provide the underpinnings for a data-driven, statistical approach to relating changes in environmental stressors to changes in ecosystem services without the need for ecosystem process simulation models. A working group of ecologists and economists will investigate the usefulness of various indicators of ecological conditions for such an approach.

4.6 Estimating Monetary Values of Ecological Changes

The previous section discussed measuring or estimating the ecological effects of EPA policies and actions. Estimating monetary values for those effects, which occurs in the fourth stage of the integrated process portrayed in Figure 4, is often useful for communicating the economic implications of EPA's actions and sometimes necessary to meet statutory requirements. Very often, however, monetary values of ecological effects can prove difficult to estimate, especially for non-marketed goods and services. For EPA, conducting original valuation studies for any specific policy or action usually is not feasible, however, given the time constraints associated with performing the related economic analyses. This section discusses key issues associated with the economic valuation of ecological changes and actions the Agency will take to improve its capabilities in this area. Section 4.6.1 focuses on estimating monetary values in original studies, and Section 4.6.2 focuses on improving benefit transfers.

4.6.1 Conducting Original Valuation Studies

Ecological entities that are bought and sold, such as commercial fish species and timber, are relatively straightforward to value. The market price might not reflect their full social value, but it has the advantage of being easy to measure and may capture most of the value. In most situations, however, analysts must infer the value of ecological changes from studies of human behavior or surveys

1 of peoples' preferences. This can be done as part of an evaluation of a specific regulation, policy or
2 program, or can be done generically, to provide estimates of value that may be applicable to multiple
3 types of Agency actions. There are many approaches to estimating value, and EPA analysts will
4 choose the approach most suited for assessing the action and the ecological changes concerned.

5
6 *Issue: Describing and measuring changes in the endpoints to be valued in stated and*
7 *revealed preference studies of ecological resources.* any policy options affect ecosystem goods or
8 services that are not directly traded in markets, and EPA analysts may use stated and revealed
9 preference methods to estimate their value. What exactly is changing – the focus of the valuation
10 exercise – and how it is measured require careful consideration. A recreational demand study for
11 ecosystems or sites impacted by a policy, for example, may not be useful if the effects of species
12 abundance or diversity on the behavior of users are not explicitly considered. Investigators need to
13 include the ecological endpoints (either direct or indirect) for which changes will result in changes in
14 economic commodities or services (e.g., how changes in bird population density affects hunting
15 demand). This is particularly true for endpoints that provide value indirectly by supporting another
16 good or service that people value directly. For example, people may not hold high values for benthic
17 invertebrate populations, but they do value recreational fisheries which depend upon them.

18
19 A valuation study should assess changes in endpoints that people care about and that are
20 among those affected by the policies or actions under consideration. Thus, if people care about water
21 quality only insofar as it affects a species' population, an appropriate revealed preference study would
22 be based on data collected on that population, while a stated preference study would depend on
23 scenarios depicting changes to that population. Moreover, there may be a variety of ways in which to
24 measure what people care about, more than one of which may be required to sufficiently describe a
25 change that results from an EPA action. Changes in biota (the flora and fauna of a region), for example,
26 may be depicted in terms of species' absolute and relative abundance, diversity, and viability. Finally,
27 multi-metric indicators (i.e., indices that combine values for several metrics into a single index value) of
28 ecological change have an as yet largely unexplored potential to facilitate ecological benefits
29 assessments.

30
31 *Action: Expand use of focus groups to identify relevant commodities and useful measures*
32 *of them.* Researchers typically use discourse-based (e.g., focus groups) approaches when designing
33 survey instruments to clarify participants' frames of reference and terminology. Instead of simply
34 seeking comment on a draft survey instrument, economists need to allow focus-group participants
35 greater opportunity to express how they think about ecological resources and even to develop opinions
36 through deliberation. In particular, focus groups can provide economists with a better sense of what
37 changes are meaningful to the public, both in terms of what is changing and how it is measured. This
38 will not only inform and potentially transform the scenarios posed in stated preference surveys, but also
39 the ecological data collected for revealed preference exercises. Focus groups can also discuss which
40 multi-metric indicators might reduce analytic complexity to a manageable level for survey and model
41 design. EPA will promote expanded use of focus groups in valuation surveys conducted by the

Agency. EPA also will consider this factor in evaluating extramural research proposals (e.g., STAR grants) for funding.

Action: Include ecologists in development of survey instruments. Section 4.5 describes EPA's strategy to improve estimates of changes in ecosystems, but precise estimates might not be possible. Therefore, EPA may utilize generic studies that estimate value for plausible changes in ecosystems. To obtain accurate estimates of value, changes to the ecosystem must be accurately described. Where quantitative links cannot be made between ecological services that people value directly and other ecological endpoints upon which those services depend, clear qualitative descriptions of impacts must be provided to survey respondents. EPA will include both economists and ecologists in the design and testing of survey instruments to ensure that background information and survey questions elicit accurate responses. EPA also will encourage this practice in extramural survey design.

Issue: Ability of surveys to elicit preferences from respondents. The hypothetical scenarios posed in stated preference surveys should be realistic and sufficiently detailed for respondents to make well considered choices. However, economists currently do not have a full understanding of how people conceptualize ecosystems and ecological goods and services. Moreover, "content validity" presents a formidable challenge to survey design in this valuation context, because respondents have been found to be quite sensitive to the manner in which a survey poses scenarios relating to ecological services. Finally, in certain cases, consumer choice theory may not necessarily explain consumer preferences related to ecosystem services; more effort is required to define the boundaries within which application of stated preference methods is acceptable (Gowdy and Mayumi 2001). To be able to consistently design reliable stated preference surveys that reflect the public's concept of ecological benefits, economists need a better understanding of how the public perceives ecological goods and services.

Action: Expand use of focus groups and debriefing sessions to identify the boundaries of appropriate use for stated preference techniques. As for the previous issue, expanding the approach used to conduct surveys can provide researchers a better sense of which changes are amenable to valuation and which are problematic, either in terms of content validity or more fundamentally. Using debriefing sessions in survey pretests, in addition to allowing participants greater latitude for thinking and deliberation, would be invaluable in identifying concepts and descriptions of them with which participants are more or less comfortable. EPA will promote expanded use of debriefing sessions in its own surveys as well as encourage it in extramural research.

Action: Expand use of combined revealed and stated preference methods. In theory, corresponding revealed and stated preference results originate from a single underlying utility function. Therefore, anchoring the non-use values to estimation of use values via revealed preference studies lends validity to stated preference estimates. In addition, estimating use values using both revealed and stated preferences garnered in a single study, and comparing the results, can provide understanding of how people respond to particular types of stated preference questions. EPA will undertake these combined studies in its own research as well as encourage them in extramural research.

***Issue:** Valuing changes in ecosystem services from changes in environmental stressors.*

Valuation research has seldom addressed ecosystem services other than the provision of valued species and aesthetic qualities; other ecosystem services are seldom accounted for in benefits assessments. Examples of ecosystem services for which valuation data are limited include ground-water recharge, pollination of agricultural crops, agricultural pest control, maintenance of soil fertility, and mitigation of storms, floods, and droughts.

***Action:** Expand use of “production functions” for valuing ecosystem services.*

Ecosystem services often can be related to private goods and services in that they serve as inputs into their production. Models that describe this relationship are known as “production functions.” If such a production function can be estimated, then the value of changes in one or more of the ecological inputs can be estimated by valuing of the change in the output using market-based or revealed preference approaches. EPA will support research that focuses on production functions that have ecological changes as inputs, particularly where those changes are likely to result from implementation of Agency policies. EPA will emphasize research on ecological production functions that can be transferred to a variety of policy and geographic contexts.

***Issue:** Interactions between ecological changes and economic uses.* The benefits of environmental management actions may be enhanced or diminished by interactions between changes in the ecological resource (e.g., species abundance) and the intensity of use of those resources. Economists who study renewable resources often use “bio-economic” models that incorporate simple models of population dynamics into economic models, yet those are seldom employed in ecological benefits assessments.

***Action:** Expand use of linked ecological-economic models in ecological benefits assessment.* Bio-economic models have been applied primarily to fisheries and forests, to understand interactions between harvesting, population changes in the resource, and economic outputs. EPA managers will encourage analysts to apply this type of modeling approach where it can improve estimates of the use values of species affected by policy. For example, a bio-economic model might be needed to assess whether protection of a given waterfowl habitat would encourage recreation to the extent that the habitat eventually would be degraded by the recreators, undercutting the aggregate benefit of the action.

4.6.2 Benefit Transfer

***Issue:** Using existing valuation studies for benefit transfer.* Because it usually is not feasible to conduct original valuation studies for a benefits assessment, EPA analysts often use values estimated for similar ecological goods and services from existing studies, a practice called “benefit transfer.” There are limitations to using benefit transfer in BCAs for Agency actions, however. Peer-reviewed publications favor methodological advances over repeated application of the same methods.

1 Thus, there is a shortage of relevant data in the literature for benefit transfer. The same approaches or
2 models tend not to be reused to estimate additional values in similar contexts (e.g., a birding valuation
3 approach might not be applied to other birding sites, other species, or other types of wildlife viewing
4 activities). In addition, even published valuation studies that focus on appropriate goods and services
5 may not be transferrable to a policy context owing to aspects of the study design that reflect its
6 different intended use. Generally speaking, there is a need for studies that use endpoints that are as
7 broadly applicable as possible across stressors, space, scale, and ecosystem type.

8
9 Very small, or marginal, changes are important for EPA benefits assessments, because most
10 regulatory actions mitigate or reduce stressors in the environment incrementally; they rarely eliminate
11 them. However, many existing studies value the entirety of a good or service rather than small changes
12 in quantity or quality of the service that may result from a specific management action. Thus, results
13 from such studies are not applicable to Agency actions that prevent incremental deterioration of the
14 environment.¹⁵ Results from such studies also are ill-suited for valuing discrete changes resulting from
15 an EPA action if the changes are different from those assessed in the study. This may prove relevant
16 because ecological processes are characterized by discontinuities such that a seemingly modest effect
17 can ultimately lead to a large change in ecosystem state (e.g., collapse of the ecosystem, conversion to
18 a different type of ecosystem). In general, studies that use continuous measures of both baseline
19 ecological condition and change are more useful for benefit transfer than those that use discrete
20 measures.

21
22 *Action: Encourage researchers to estimate values for a wider variety of ecological*
23 *resources.* EPA will participate in activities that further research on ecological benefits for which few
24 valuation data currently are available. Examples of recreational benefits for which valuation data are
25 lacking include non-consumptive types such as birding, hiking, and scuba-diving. As mentioned in
26 Section 4.6.1, EPA also will encourage research into production functions that relate to the private
27 goods and services supported by ecosystem services.

28
29 *Action: Encourage researchers to use standardized measures of ecological resources in*
30 *valuation studies.* One way to make it easier to transfer estimated values from a published study to
31 new situations is to encourage researchers to use one or more of the generic ecological benefits
32 assessments endpoints discussed in the second action in Sections 4.3 and the first action in Section
33 4.5.3. Studies should be broadly applicable to other areas and situations. EPA will publicize its need
34 for generalizable studies through a variety of activities, including participation at meetings or symposia,
35 mention in EPA publications as appropriate, and emphasis in its requests for proposals under EPA's
36 STAR grant program, where transferability could be considered a primary criterion for funding.

37

¹⁵What is marginal is fundamentally a matter of defining the scale of analysis. A loss of one entire wetland
in an area with many similar wetlands, such as the prairie pothole ecosystem, would be considered marginal to that
particular regional ecosystem.

1 Action: *Encourage researchers to estimate and report values for a greater range of*
2 *ecological changes.* Through activities similar to those noted above, EPA will encourage researchers
3 not only to value marginal changes, but also to estimate and report demand curves or willingness-to-
4 pay/willingness-to-accept compensation (WTP/WT A) profiles over a large range of resource
5 abundance. For example, a stated preference study might elicit responses concerning the value of small
6 changes in the extent of natural areas using a series of baseline sizes instead of one baseline size. Such
7 data would allow analysts to value discrete, as well as marginal, changes of interest.

8
9 Action: *Support the development of new publication outlets.* EPA will support the
10 development of publication outlets for high quality valuation research projects that use existing methods
11 to investigate multiple endpoints and areas relevant to EPA policy analysis. These outlets could be print
12 or online journals, books, or workshop proceedings. Researchers could potentially publish
13 methodological advances in an existing journal and more detailed policy-relevant results in the new
14 outlets. EPA's support may be financial, in-kind, or by encouraging sponsored researchers to publish
15 in these outlets.

16
17 Issue: *Estimating ecological benefits from multiple values.* In benefit transfer exercises, the
18 analyst is faced with cobbling together a total economic value from multiple estimates, each dealing with
19 particular affected goods and services or particular benefits. For example, a stated preference study
20 might estimate the total value of a species or ecosystem, while a recreation demand study necessarily
21 focuses on only the recreation benefits of that species or ecosystem. In this case, it may be difficult to
22 avoid double counting. In addition, the analyst may also have to consider multiple values that purport
23 to relate to roughly the same change (i.e., that overlap). There is some literature published on why
24 different valuation studies for the same change in a specific ecological good or service produce
25 divergent results, but economists still have much to learn in this area. Because of idiosyncratic factors
26 that cannot be accounted for, sound estimates of the same benefit may look quite different. In this case,
27 selecting a single study from the set may open EPA to charges of bias in its selection.

28
29 Action: *Support research on methods for combining independent value estimates for*
30 *benefit transfer.* Meta-analysis is a set of techniques that synthesize the summary results of empirical
31 research and can be used to combine independent estimates of values as provided in existing studies.
32 By systematically examining the influence of study-specific factors on values in different studies, it can
33 be used to predict values for policy sites which are unlike any particular site as described in the existing
34 studies. EPA will encourage meta-analysis, a standard practice for other disciplines, in its
35 recommendations for future research.

36 37 38 **4.7 Supplemental Approaches**

39
40 Estimating the value of ecological changes in monetary terms is often useful because dollars are
41 familiar and different ecological benefits stemming from an action can be easily combined and compared

1 to costs. Normally, however, it will not be possible to place monetary values on all quantified
2 ecological changes, because existing methods, models, and data are inadequate. In situations when
3 many valuable characteristics can only be described qualitatively or measured in bio-physical units but
4 not monetized, BCAs may not be appropriate. Therefore, supplemental methods for evaluating
5 ecological changes may be needed for decision-making.

6
7 Moreover, even where monetary estimates are feasible, there has been extensive debate about
8 whether decisions based on monetary valuation can adequately protect ecosystems in the near term and
9 create sustainable conditions over the long term. Progress in resource and environmental economics
10 has broadened the scope of ecosystem services that can be included in economic analyses, but the
11 most widely used methods measure value as WTP for a good or service as determined by market
12 behavior or other observed or stated individual preferences. Various criticisms have been made
13 concerning the reliance on individual preferences, as economists currently measure them, as a basis for
14 policy evaluation. Those criticisms generally pertain to three lines of argument, which are not entirely
15 distinct from one another, as described below.

16
17 The first line of argument concerns the rationality and stability of individual preferences.
18 Cognitive psychologists have argued that the elicitation methods common to stated preference
19 techniques tend to be more visceral than intellectual and analytic, and that more highly structured
20 elicitation tasks are needed to reliably support policy (Fischhoff 2004). Gowdy (2004) points out that
21 preferences have been shown to be context-dependent (“endogenous”) in ways that violate the
22 assumptions on which welfare measures are based. A second argument is that preferences usually are
23 elicited in isolation from the public discourse that characterizes democratic processes. Proponents of
24 discourse-based methods have argued that people’s private preferences about their own consumption
25 opportunities are not equivalent to the principled judgments those same individuals would express in the
26 arena of public policy-making (Sagoff 1998) nor to the views they might arrive at through a process of
27 open debate and deliberation (Wilson and Howarth 2002). A third line of argument, which stresses the
28 complexity and biophysical limitations of ecological-economic systems, questions whether individuals
29 have enough specialized knowledge or receive adequate feedback to recognize either the long-term or
30 the sudden and irreversible ecological changes that their actions may help to precipitate (Costanza
31 1991, USEPA 2000c).

32
33 To a certain extent these criticisms argue for the continued refinement of existing economic
34 methods. But they also highlight certain underlying limitations of approaches based on individuals’
35 preferences and suggest that constructive, discourse-based or systems-based approaches may provide
36 complementary information about benefits. Various assessment approaches that have been proposed
37 in response to one or more of these criticisms are described in more detail in this section. Many of
38 these are policy evaluation approaches rather than benefits assessment approaches per se; that is, they
39 co-evaluate ecological benefits together with other outcomes rather than provide estimates of ecological
40 benefits by themselves.

Two broad categories of assessment approaches are described below. Section 4.7.1 discusses weighting or ranking procedures, in which groups of experts or interested and affected parties rate the importance of diverse objectives. This approach can take advantage of specialized or local knowledge, allow discussion and consensus building, or involve structured approaches for construction of preferences. Section 4.7.2 describes systems-based methods. These often measure biophysically limiting factors or may identify desirable, ‘emergent’ properties or states of ecological-economic systems that transcend single measures. They often model ecological and economic structures, processes, limitations, and feedbacks so as to simulate dynamic and long-term system behavior with respect to these limitations or desirable properties.¹⁶ Section 4.7.3 discusses options for combining these approaches with each other or with monetary valuation methods in different hybrid approaches.

4.7.1 Weighting/ Ranking Procedures

Weighting or ranking procedures can be used to compare alternative ecosystem states according to multiple objectives. They also can be used to compare management alternatives according to how well multiple objectives are achieved. Comparison approaches can range from informal, such as individual votes following brief discussion, to highly formal, such as the Delphi method in which expert opinion is refined through iteration and feedback. Some, but not all, of these are multi-attribute approaches, in which diverse management objectives are articulated as individual attributes. The degree to which a given management alternative fulfills a given objective is scored, usually by technical experts, and the relative importance of each of the objectives to the overall decision is weighted by decision-makers, stakeholders, or the general public.¹⁷ Advantages of multi-attribute approaches that have led to their wide use in ecological resource management include the ability to incorporate public values into decisions that are too complex for individual preference-based approaches and the ability to co-evaluate monetized and nonmonetized attributes (Prato 2003). Whenever policy-related changes in ecosystem services are included among the attributes evaluated in a comparison, then an implicit ecological benefits assessment is being performed.

A example of implicit valuation by ranking that is familiar within EPA is the 1987 *Unfinished Business* report on comparative risks, in which panels of EPA scientists and managers ranked 31 environmental problems as to their relative risks to human health, ecological systems, and human welfare (USEPA 1987d). The problems varied widely as to magnitude and extent of stress and

¹⁶Multi-metric indices such as the index of biological integrity (IBI, see Section 4.5.1) are not considered valuation approaches for purposes of this discussion. They are useful for summarizing many ecological measures, but usually are limited in scope to a single resource category (e.g., the condition of a stream’s fish assemblage) and management objective (e.g., achieving a healthy fish community). They are therefore of limited use for evaluating trade-offs among multiple objectives (e.g., achieving a healthy fish community, improving migratory bird habitat, and minimizing costs).

¹⁷By contrast, approaches in which individuals or groups evaluate alternatives in their entirety, rather than according to individual attributes, have been termed holistic.

1 severity and form of adverse effect. The resulting prioritizations, which necessarily aggregated across
2 those factors, differed substantially from the implicit rankings of Congress and the public. This
3 difference is not unexpected given the panelists' specialized knowledge, but could also be attributed to
4 their divergent interests vis-à-vis the general public. Nonetheless, a follow-up study by EPA's SAB
5 called for the further development of procedures for risk ratings by technical experts (USEPA 2000c).
6 An important element of the SAB's rationale was what it described as the inherent difficulty of
7 accurately and comprehensively valuing ecological changes using economic methods. Subsequent
8 STAR grant-funded work at Carnegie-Mellon University explored the use of both articulated (i.e.,
9 multi-attribute) and holistic approaches for the evaluation of health and environmental risks by experts
10 and laypersons, performing as individuals or in jury-like (i.e., deliberative) groups (DeKay et al. 2001,
11 Morgan et al. 2002, Willis et al. 2004). These researchers found that use of a process combining
12 individual and group surveys and holistic and multi-criteria ranking methods tended to inform the
13 participants, yield consistent results, move group members toward agreement, and produce high
14 participant satisfaction ratings.

15
16 *Issue: Extending the use of risk-rating techniques to the evaluation of management*
17 *alternatives.* Structured comparison procedures could be used to inform individuals or groups about
18 the ecological (and other) attributes of different policies and enable them to rate or rank those policies
19 directly. The SAB and Carnegie-Mellon efforts were limited to the evaluation of risks. Risk rankings
20 are informative in a general sense but do not directly address the trade-offs involved in decisions among
21 policy alternatives. The Carnegie-Mellon researchers considered the use of similar techniques to rate
22 management options, as well as risk, to be desirable but problematic, because the set of potential
23 management options in any given situation would be practically unlimited (DeKay et al. 2001). This
24 objection seems easily overcome, however, since it is common to delimit an option set before full
25 evaluation. Indeed, Gregory and others (Gregory and Slovic 1997, Gregory et al. 1997) call for the
26 use of multi-attribute, environmental valuation and problem-solving approaches that combine small-
27 group structuring of values and objectives followed by individual rating of management alternatives
28 according to those objectives. Concerns with the use of such approaches, however, include the
29 stability of the methods used and the normative implications of various procedures for participant
30 selection.

31
32 *Action: Study the applicability of various rating and ranking procedures as a complement*
33 *to BCAs.* EPA will sponsor a study that considers the approaches used to date, including those relying
34 on experts and laypersons, individuals and groups, and holistic and multi-attribute problem descriptions.
35 The study will take into account the three issues raised above (i.e., the rationality or stability of values
36 elicited by each approach, the degree to which an approach reflects democratic processes, and its
37 ability to reliably and objectively describe the long-term ecological, financial, and social outcomes of
38 policy alternatives). The study also will evaluate the degree to which the approach is applicable to
39 actions of the type and scale made by EPA, including its appropriateness for use at site-specific and
40 national scales. Answers to these questions will form the basis of comparison with WTP-based
41 valuation approaches.
42

4.7.2 Approaches Based on Properties of Ecological-economic Systems

Limitations to estimating, and appropriately interpreting, monetary valuations have also stimulated efforts to develop biophysically-based approaches to valuing ecological benefits. These approaches quantify the demands placed on ecological systems by economic processes and seek to directly incorporate biological or physical limits, such as those imposed by the laws of thermodynamics. Nicholas Georgescu-Roegen (1971) pioneered many concepts in this area. He argued that all activities rely on the energy available in a materially closed system, and that trade-offs can be considered in terms of the amount of low entropy dissipated. Since ecosystems are a store of this ultimate “input,” low entropy, its dissipation when ecosystems are degraded or lost for the sake of economic activity ought to be accounted for as another cost of production. The implications of his work have been widely debated, in journals such as *Land Economics* (Burness et al. 1980, Burness and Cummings 1986, Daly 1986, Norgaard 1986) and a special issue of *Ecological Economics* (Daly 1997).

One family of analytical methods in this area treats various forms of energy as the biophysical and economic least-common-denominator. Costanza (1980) uses “embodied energy,” that is, the energy used to produce goods and services in national economies. Odum (1996) suggests that “emergy,” the solar energy captured by living and nonliving earth systems and transformed by physical or biological processes, represents the “real wealth” of both ecosystems and human economies. Others quantify the properties of ecosystems by the energy that is available (“exergy”) (Jørgensen 1997) or unavailable (“entropy”) (Faber et al. 1996). Some of these energy measures have further been assumed to represent emergent properties of complex systems, for example indicating a system’s stability or dominance (i.e., its tendency to replace competing systems), which could be used to determine the preferability of one system state compared to another, thus providing a basis for valuation. Others consider thermodynamics to be important but doubt the sufficiency of energy-based indicators alone to describe optimal system states. This school of thought perceives the importance of thermodynamics as imposing a real constraint on the scale of the macro-economy and/or serving as a focal point for learning and analysis related to sustainability, contingent on ethically based decisions by society to pursue a sustainable path (Daly 1986, 1992; Söllner 1997).

“Ecological footprint” methods similarly treat the area of land (i.e., ecosystems) needed to support human activities as a limiting, least-common-denominator by which alternatives can be compared (Rees and Wackernagel 1994, Folke et al. 1998). These methods likewise have been discussed in a special issue of *Ecological Economics* (Costanza 2000a) and have been described as overly simplified, technologically pessimistic, and biased against trade, but also as effective aggregators of diverse ecological and economic information and powerful macro-level illustrators of the ecological demands of economic activity, which often go unrecognized (Costanza 2000b).

Issue: Usefulness of ecological-economic systems approaches for EPA decision-making. Questions have persisted among EPA scientists and in the academic community about the ability of monetary valuation methods to adequately address key issues of ecosystem quality, ethics, and sustainability, suggesting that alternative methods should receive greater attention at EPA.

Action: Evaluate the utility of selected ecological-economic systems properties for environmental decision support. EPA will sponsor a study to determine the strengths and weakness of various approaches in a manner similar to that described above for the evaluation of weighting/ranking approaches. In addition to the issues raised above, the study of these approaches will give special attention to the following questions about the property used as a least-common-denominator:

- How clearly and demonstrably is the property related to human or ecological well-being (and thus a potential basis for policy)? What normative assumptions would underlie its use?
- Can the property be used to effectively describe the condition of ecological systems, economic systems, or both?
- Is the property reliably and replicably measurable (for ecological systems, economic systems, or both)?

4.7.3 Hybrid Approaches

The weighting/ranking and biophysical systems-based approaches described above are not mutually exclusive, since policy evaluation can combine elements of both, nor are they wholly incompatible with monetary valuation methods. Various hybridizations of preference-based approaches with constructive, discourse-based or systems-based approaches might be useful for addressing valuation problems. For example, many economic valuation studies use discourse-based (e.g., focus-group) approaches in the course of survey instrument design to clarify participants' frames of reference and terminology, but the procedures used may not be systematic and are rarely reported. Gregory et al. (1997) advocate the use of deliberative techniques that establish hierarchies of stakeholders' values as a formal element of survey design. In the Puget Sound Regional Integrated Synthesis Model (PRISM), Alberti and Waddell (2000) link a random utility (i.e., preference-based) model of urban parcel purchases with ecological simulation of land development impacts, including feedbacks to attractiveness of land parcels for purchase.

Issue: Establishing the linkages between ecological, economic, and social science methods in support of new valuation approaches. Transdisciplinary approaches hold promise for improving ecological valuation, yet the methods used to date are often ad hoc, experimental, or resource intensive, and they have remained beyond the periphery of EPA policy-making.

Action: Conduct trial applications of hybrid decision approaches in upcoming benefits assessments. For program offices requesting assistance with upcoming benefits assessments, ORD and NCEE will assist in interdisciplinary working groups assembled to attempt hybrid decision approaches to the benefits valuation. The working group will evaluate approaches using the criteria

- 1 defined previously. The resulting review and discussion can help to pave the path to improving these
- 2 approaches and to the development of an expanded policy evaluation toolkit.

5 Implementation

The *Ecological Benefits Assessment Strategic Plan* (EBASP or “the Plan”) lays out a roadmap for an incremental and sustained effort that will steadily improve the Agency’s ability to identify, quantify, value, and communicate the ecological benefits of its environmental management actions. The EBASP distinguishes itself from previous efforts by focusing on the full scope of ecological benefits assessment at EPA (Sections 3.1 and 3.2 and Sections 4.3 to 4.7) and by suggesting activities and institutional changes that will lead to Agency-wide coordination of efforts to improve ecological benefits assessment (Section 4.2 and this Section). Past activities generally have been initiated by different offices independently, without explicit expectations for follow-on activities and without procedures for implementing recommendations. Despite recognition of the need for improved capabilities in ecological benefits assessment across many program offices, EPA has not yet established an Agency-wide mechanism for addressing this need. To ensure continued progress, this section identifies three areas for additional Agency actions needed to implement the EBASP. These areas focus on identifying future investment priorities (Section 5.1), aligning resources to those priorities (Section 5.2), and creating mechanisms to sustain incremental improvement over the long term (Section 5.3).

5.1 Identifying Future Investment Priorities

Section 4 of the EBASP describes most actions for improving ecological benefits assessment at a general level, rather than defining specific, detailed projects. Individual EPA program offices face disparate needs related to ecological benefits assessment. To enhance Agency understanding of program-specific research and development needs, each office should create its own Action Plan, based on its mission and the opportunities identified in the EBASP, to help guide future investments. The Action Plans will specify projects in some detail, and will be updated periodically to reflect new needs and the expected advances in ecological benefits assessment. A number of mechanisms can be used to inform development of Action Plans, including rule- and program-specific problem formulation exercises like those described in Section 4.2.2 and conducted for Office of Water programs in 2004. Other mechanisms include structured analyses of past ecological benefits assessments to identify limitations, and brainstorming interviews with program ecologists and economists to identify opportunities for improvement. The purpose of these activities is to identify relevant ecological and economic endpoints, to determine needed data, models, and assessment methods, and to identify outstanding research and development needs. Specification of time frames within which these needs should be addressed will help to establish investment priorities.

5.2 Aligning Resources

1 Research conducted by the Agency can be categorized as *problem-driven* or *core* (USEPA
2 2001c). Problem-driven research focuses on specific environmental problems reflecting immediate
3 regulatory and policy requirements. Core research seeks to improve fundamental understanding of the
4 key biological, chemical, physical, economic, and human behavioral processes that underlie
5 environmental systems, which will prepare the Agency to meet future problems and challenges.
6 Problem-driven and core research are not entirely separable. In fact, they are highly complementary
7 and interactive, each informing the other to yield a robust research portfolio focused on the mission
8 needs of the Agency. Both problem-driven and core research contribute to EPA's ability to conduct
9 ecological benefits assessments by improving the Agency's understanding of ecological and economic
10 systems. This Plan is the first to articulate both problem-driven and core research needs specifically
11 within the context of ecological benefits assessment.
12

13 As the principal scientific and research arm of the Agency, the Office of Research and
14 Development (ORD) plays a unique role in developing the ecological science and technology needed to
15 fulfill EPA's environmental and human health protection mission. The Office of Policy, Economics, and
16 Innovation (OPEI) meets a similar need with respect to economic science. ORD engages in a multi-
17 year planning process, which identifies and communicates the direction of its research program in five-
18 to ten-year time horizons. That direction is based on Agency priorities, direction from ORD senior
19 leadership, and external input. Research Coordination Teams (RCTs) play a key role in ORD's
20 research planning process and are responsible for coordinating research planning with the program
21 offices and EPA regions. An important outcome of the planning process is the alignment of resources
22 to best address Agency needs.
23

24 This Plan has identified a number of research areas and institutional changes for improving
25 ecological benefits assessments at the Agency, but it has not laid out a specific set of priorities or
26 assigned tasks or time lines to particular EPA offices. ORD and OPEI, working within current research
27 planning structures and in collaboration with all relevant program offices and other stakeholders, will
28 develop a systematic method to guide prioritization of the investment opportunities identified in the Plan
29 and individual program office Action Plans, so that the Agency can efficiently and effectively align its
30 resources (including extramural grants) to address these issues. Criteria by which to prioritize Agency
31 investments include those listed in Text Box 3. In general, however, the Agency will rank actions
32 according to their contribution to improving benefits assessment and their cost effectiveness. The
33 Agency will use this prioritization to guide research investments of ORD, OPEI, and individual program
34 offices, and to communicate and coordinate needed research with external partners. Section 5.3
35 identifies a cross-Agency mechanism to facilitate prioritization of specific actions and alignment of
36 resources.
37
38

5.3 Sustaining Improvement Efforts

A sustained research and development effort is needed to improve the Agency's ability to assess ecological benefits. Tracking progress and integrating ecological benefits assessment into the Agency's base programs are essential to ensuring successful implementation of the EBASP. While ORD already is a significant investor in research related to ecological benefits assessment, EPA lacks a process for highlighting the importance of ecological benefits assessment throughout

Text Box 3. Considerations for prioritizing Agency actions to improve economic assessment of ecological benefits.

The extent to which the action fills an urgent or important gap. In general, the information needs identified at the interface between ecology and economics create a "bottle-neck" for ecological benefits assessments. There are additional "show stoppers" both on the ecological and economic side of the ecological benefits assessment process.

Significance of the action to multiple EPA programs, regulations, and policies. Actions that result in data, tools, methods, or institutional changes that assist several programs or a number of regulations and policies are most beneficial.

Opportunity for collaboration across disciplines. In view of the analytical and (sometimes) ethical divide between ecologists and economists and the importance of collaboration, actions that involve economists and ecologists working closely together on a particular aspect of the ecological benefits assessment process are highly valued.

Opportunity for leveraging inter- and intra-Agency resources and expertise. There are many professionals with expertise relevant to ecological benefits assessment across EPA, other agencies, academia, and the non-profit and public sectors. Actions that draw on this collective expertise are preferred. Collaboration within and among agencies results in sharing of data and methods (minimizing costs and improving efficiency) and in building the collective capacity to

the Agency's programs. Additionally, mechanisms for communicating research needs as well as results are needed to facilitate attainment of the objectives set out in Section 1.1 of this Plan. Some of these mechanisms are described in Section 4.2. Two final mechanisms focus on establishing cross-Agency groups to help coordinate implementation efforts and to promote long-term improvement activities.

The first mechanism is the establishment of a high-level Agency oversight committee with technical and management representation from across the Agency to track progress and to integrate ecological benefits assessment into Agency programs. This group will meet regularly to discuss general progress toward program-specific and Agency-wide goals, focusing on coordinated work plans and

1 long-term research. This group, to be charged by the Administrator upon endorsement of this Plan,
2 also will track the progress of the Agency in addressing actions and institutional changes described in
3 the EBASP and in program office Action Plans. The oversight committee will establish a specific
4 approach and time line to accomplish its mission. Activities that this group can initiate immediately are:

- 5
6 1. Develop mechanisms for sharing information with outside analysts and academics;
- 7
8 2. Initiate training opportunities relevant to ecological benefits assessment;
- 9
10 3. Develop guidance materials;
- 11
12 4. Develop mechanisms to facilitate understanding of priorities and to promote allocation
13 of resources to address the research needs identified in the EBASP and in program
14 office Action Plans; and
- 15
16 5. Develop and track performance goals and measures to communicate the intentions and
17 success of EPA's efforts to improve ecological benefits assessment.
- 18

19 The second mechanism is establishment of an Ecological Benefits Assessment Forum (EBAF).
20 Similar in concept to the Agency's existing Economics Forum and the Risk Assessment Forum, the
21 EBAF will serve as a central point at the staff level for Agency-wide communication, discussion, and
22 evaluation of cross-cutting issues related to ecological benefits assessment. Charged by and reporting
23 directly to the oversight committee, the EBAF will identify opportunities for coordinating activities
24 across program offices, track and communicate progress in improving ecological benefits assessments
25 across offices, assist in identifying Agency-wide priorities, and forecast emerging needs. In
26 coordination with the Economics Forum and the Risk Assessment Forum, the EBAF will assist
27 program offices as requested in developing Action Plans and will facilitate collaborative efforts. The
28 EBAF also will be responsible for developing specific products related to ecological benefits
29 assessment that have wide use across EPA (e.g., guidelines for ecological benefits assessments and the
30 generic ecological benefits assessment endpoints projects described in Section 4.3).

31
32 Improving EPA's ability to conduct ecological benefits assessments will take time – the Agency
33 needs to facilitate interdisciplinary and cross office communication, to establish priorities, to align
34 resources, and to plan and conduct specific research. Some of the actions identified here and
35 elsewhere in the Plan can be implemented immediately, while others will require incremental changes in
36 Agency practices and priorities. Upon full implementation, the roadmap of research needs and
37 institutional changes provided by this Plan will ensure continuous improvement in the Agency's
38 ecological benefits assessments.
39

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